JOURNAL

OF

THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

OCTOBER, 1863.

## CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

*Papers on Hydraulic Engineering.* By SAMUEL MCELROY, C. E.

(Continued from Vol. xlv, page 309.)

### No. 4.—CITY SEWERAGE.

THE subject of city sewerage, holds an intimate relation to that of water supply, and both take a high rank in their effects on public health and comfort. Each, in its place, is an index of civilization. In cities of recent formation and rapid growth, like most of those in this country, progress in works of this class has followed the demands of necessity, and for want of proper foresight and precaution, completeness of system is not the general rule. The general introduction of water, involves the construction of sewerage, for its proper discharge, but it is rare to find both improvements under construction by a joint administration, or practically executed as parts of a common public measure.

It is common in our advancing and condensing communities, to look on this special work of sewerage, as a matter to be attended to, only as local improvements demand it, and there is a general and prudish popular dislike to its thorough examination and discussion, as disagreeable and unrefined. But it is the prerogative of true science in this direction, as of art in another, to dignify and ennoble those things which ignorant and vulgar minds may consider common and unclean,

and to anticipate for every collection of human beings those precautionary measures, which the wants and necessities of humanity render imperative, and which belong to the great field of national improvement and elevation. In the whole experience of human life, as it has pleased the Divine Creator to establish and control it, as to its organic necessities and infirmities, there can be nothing intrinsically or inherently degrading, and the conditions arising from the very wants of mankind, full of daily and hourly importunity, furnish the best opportunities for upward development of the superior faculties. There can be no Christian charity or true courage in the spirit which turns away from what seem to be the disagreeable circumstances of daily life, in persons or communities.

There are no more eloquent chapters in "*Les Miserables*," than those which chronicle the heroism of *Bruneseau*, the engineer of the Parisian improvements in sewerage, from 1805 to 1812. The vivid descriptions by the brilliant author, of the vast underground Paris, "tortuous, fissured, unpaved, crackling, interrupted by quagmires, broken by fantastic elbows, rising and falling out of all rule, fetid, savage, wild, submerged, in obscurity, with scars on its pavement, and gashes on its walls," which was systematically explored, surveyed, mapped, and reconstructed in part by this intrepid engineer and his assistants, fully justify his eulogy from Napoleon's own Minister of the Interior, as the "boldest man" of that empire of braves, and his name deserves something more than a passing reverence.

In great sanitary works of this class, it is evident that the modern world is behind the standards of ancient precept and practice. Particularly in our own country, which prides itself on advanced civilization, there are few examples of studied and comprehensive works.

So careful were the ancients, when congregated in large cities, as to matters of sanitary regulation, that distinctions were made in the quality of water supplied for domestic use, some aqueducts being prescribed for one use, and others for another. This was prominently the case with the Roman aqueducts, of which the *Aqua Marcia* was, by an imperial edict, set apart for beverage from its superior coolness and purity. In like manner, in this and other prominent cities, great care was taken of the public health, in the arrangement of places of amusement, baths, fountains, sewers, and other means of recreation, comfort, and convenience; these departments being under the charge of public officers, and forming an important feature in the civic government, while individual enterprise was permitted to exercise the most extravagant scale of expenditure in similar directions.

This public regard for public health and cleanliness, must be taken then and now, as an important index of the special stage of civilization locally attained. It is also a matter of demonstration that it furnishes a reliable index of the state of public health. Self-respect in cities and nations, as in individuals, develops itself in carefulness of proprieties, and in attention to rules, which the half-civilized and barbarian nations do not exercise; and it may be said, in this view of the subject, that the best examples of the present century, and of our

most enlightened countries, came far short of the standard of the primitive nations of South America, as defined by their still existent sanitary works, and of the nations of ancient Europe and Asia. These special lessons of human example and experience must then be recopied and practised to bring ourselves even to the level of ages which it is common to number among obsolete things in social excellence; and these considerations make it plain, even to the casual observer, that our prominent cities, have as yet but very rudely and imperfectly fulfilled one of the very first and most obvious duties to their own communities, and one of the most essential observances of general health and comfort.

*General Features.*—In presenting the principles and methods which control the judicious arrangement of a city system, in such conciseness of manner as our limits specify, and in text-book style, we shall have to consider the disposal of sewage required, as to the several kinds of matter accumulating; the necessities and the effects; the methods of disposal in ancient and modern practice; and the laws and conclusions which result and which properly control the design and arrangement of any local system.

*Disposal of Sewage.*—Every well-regulated community should be able properly to dispose of all its objectionable and noxious accumulations, under the most perfect and speedy conditions of such disposal. Economy, comfort, and health jointly demand the best accomplishment of this public duty. This sums up, in fact, the problem of city sewerage: adequate disposal in the shortest time. We shall see, further on, how grievously this problem is overlooked in general practice.

These accumulations may be classified generally as *street dirt, house sewage*, and *rainfall*, and may be noticed in their order.

*Street Dirt.*—We may assume that this is made up, in daily accumulation, of two distinct classes, viz: the garbage, ashes, and other house productions of a perishable or solid character, and the horse manure and other deposits on the streets. It is manifestly improper that the former class should be permitted to encumber any system of underground drainage, for prudential reasons. Economy dictates its removal by cartage, and good taste demands that this be done at short intervals, and without the common exposure of garbage barrels and boxes to sight and smell, for hours and days, on the sidewalks of public thoroughfares and in front of otherwise genteel residences.*

Whether the second class of street dirt should be passed into the public sewers, seems to depend on the character of the pavement and the efficiency of the sewers. Macadamized streets, or those paved with cobble-stone, or other open stone-work, which will not admit the action of a strong water jet, or which are apt to pass into the sewers substances tending to the formation of concrete, may be most economically cleaned by street-sweeping and dirt-carts; and this should be done regularly, thoroughly, and often. Neglect is a frequent source

* Quite recently an order has been issued by the Health Inspector of New York, which provides for timely notice of the approach of the dirt-carts by a bellman, and is intended to obviate the former use of garbage boxes in public view.

of public inconvenience and mortality. The daily use of light street-sprinkling, by infecting the atmosphere with noxious exhalations, aggravates the evil which it does not remove. It is also unfortunate that contracts for removal of street-dirt should be directly associated with the election or incomes of city aldermen, as local politics is always bad enough without the addition of this ingredient.

In those streets which are paved with stone blocks, or such close-jointed materials as will prevent severe water-wash, there are, without doubt, advantages on the score of cleanliness and economy, in the use of an adequate street jet and a discharge into the sewer-basins. Thus one improvement depends on another. The cobble-stone pavement, which is a rude and objectionable expedient, not merely uncomfortable to all wheeling, and costly for repairs to rolling stock, but costly for its own annual repairs, is now rapidly giving way, in many cities, to much more durable and satisfactory pavements of stone, which will properly admit the use of hydraulic cleansing, under daily applications.

The superior advantages of this method, by which a positive luxury becomes a source of great economy, in thoroughfares which properly admit it, have been made the subject of repeated experiments, as to questions of cost, reduced temperature, atmospheric purity and otherwise, in England, while the practice is maintained to a limited extent, by individual enterprise in portions of our prominent cities, Philadelphia taking special rank in this respect; but it is nowhere systematically adopted as an administrative operation with adequate appurtenances, and thus comes short of an extensive and complete demonstration.

The experience of the General Board of Health (London) Report of 1850, is thus given:—

"The trial of a jet d'eau, with a hose attached to the water main, was recommended to the Metropolitan Commissioners of Sewers, and a number of careful trials were made by Mr. Lovick, who gives a detailed account of them in his evidence. Similar experiments were also made by Mr. Hale. Some trials of this mode of cleansing had previously been made by Mr. Lee, one of our engineering inspectors. Mr. Lovick conducted his experiments with such jets as could be obtained from the Water Companies' mains in eligible places; but the pressure was low and insufficient. Nevertheless, it appeared that, taking the actual quantity of water required, at the actual expense of pumping, the paved surfaces might be washed clean at one-half the expense of the scavenger's manual labor in sweeping. Mr. Lee's trials were made at Sheffield, with the aid of a more powerful and suitable pressure, and he found that with such pressure as he obtained, the cleansing might be effected in one-third the time, and at one-third the usual expense of the scavenger's labor of sweeping the surface with the broom."

"The effect of this mode of cleansing in close courts and streets was found to be peculiarly grateful in hot weather. The water was first thrown up and diffused in a thin sheet; it was then applied rapidly to cleansing the surface and the side-walls, as well as the pavement. The immediate effect of this operation was to lower the temperature and produce a sense of freshness, similar to that experienced after a heavy thunder-shower in hot weather."

It was found in these experiments, that the quantity of water required would not exceed one gallon per square yard; and there can be little doubt that similar trials in our own cities, would give similar economical and sanitary results. Since other experiments have shown

that the surface-water from streets and house-roofs often contains as much filth as the soil-water of house sewage, there can be no objection to the use of the sewers for the former, where the system is adequate.

*House Sewage.*—This is made up of the liquid, semi-liquid, and solid matter, discharged from the kitchen-sinks, cess-pools, water-closets, baths, and other household appurtenances; and it is a matter of deduction and experimental demonstration, that it is controlled, in quantity, by the amount of water-supply, as a general rule.

As may then be readily inferred, house sewage is not difficult to dispose of, by properly arranged means, and only becomes troublesome when its flow is interfered with, in proportions of sewage water, or in the system of drains, and it becomes viscous.

It appears from the *Metropolitan Drainage Report* of 1857 (London), that with a water-supply, from the several companies, of 12,250,000 cubic feet per day, the sewage flow, as deduced from experimental gaugings, was 15,249,777 cubic feet. To the 80 per cent. of water-supply, is to be added the supply of independent streams, springs, and sources additional to that of the several companies, estimated in all at 100,854,554 gallons, on which basis the discharge of 95,311,106 gallons of sewage was to be provided for.

In the Report of the *General Board of Health* for 1850 (London), which is a much more elaborate and satisfactory document than most of those which succeed it, on the same subjects, an experiment made on the sewage flow of 1200 houses, shows an average daily sewage flow of 44½ gallons per house, while the actual average water consumption was 51½ gallons, or 5·7 gallons per person per day. It is assumed, however, that the losses from permeable brick drains, cess-pools, and otherwise, were considerable in amount, and should be added to the flow of sewage gauged.

An examination of the flow of the Boston sewers, given in the Report of 1853, which was made to detect the localities of serious water-waste, shows that in the districts occupied by the poorer class of residents, "enough was ascertained to show that all the consumption of water was more than equaled by the discharge from the sewers."

It may then be assumed, without adducing the various experiments recorded in different localities on this point, that the quantity of water-supply is a very reasonable index of the quantity of house sewage.

The estimate of house sewage assumed for the London Plan of 1857, is thus stated:—

"It will be seen that the amounts vary from 4·8 cubic feet per head in the more thickly inhabited parts of the town, occupied by a larger proportion of the poorer classes, to 8 cubic feet per head in the western districts, where the value of water for domestic purposes is more appreciated, and where the cost is less a matter of consideration; and that the average of the whole metropolitan district appears to be 5·8 cubic feet per head."

As to the time and rate of flow throughout the day, the same Report thus remarks:

"It appears that if the day be divided into periods of eight hours each, the amount which passes off into the metropolitan sewers during the eight hours of

maximum flow, viz: between 9 A. M. and 5 P. M., is 49 per cent. of the whole; whilst about 18 per cent. only flows off during the eight hours of minimum flow, which occur between 11 P. M. and 7 A. M. We have therefore assumed that half the estimated quantity of sewage will pass off in eight hours."

In this case the analogy with water supply is maintained, since it is a matter of experience with us, that more than twice the average daily water supply, is used between 8 A. M. and 5 P. M.

*Rainfall.*—Provisions for the proper disposal of ordinary and extraordinary rainfall by the sewers, must be made.

The nature of the surface covered by the rainfall, and to be drained by the sewers, whether closely built upon and paved, or otherwise, will affect the rapidity of discharge; as also the partially saturated or dry condition of the areas, gardens, and other open parts at the time.

Some experiments show "in a town district, such as that drained by the Savoy and Northumberland street sewers, the quantity running off into the sewers within six hours after the fall of rain varies, from 10 to 60 per cent. of the quantity fallen; while in a suburban locality, such as the Counter's Creek Sewer Drains, the quantity reaching the sewers would vary from 0 to 30 or 40 per cent., in 24 hours after the rain, according to the previous conditions of the surfaces, the remainder being carried off by evaporation, absorption, and other causes." *London Report*, 1857.

Other London experiments on actual discharge, for sewers draining large districts, give from 52 to 64½ per cent. of the total rainfall, the former in 25 hours, and the latter in 36 hours duration. By some authorities the available rain supply is taken at two-thirds of the fall; and this is considerably in excess of the available supply, usually estimated for water-works purposes.

The London rainfall is considerably less than in this country. The general summary of a table reported in 1857, has the following subdivision:—

| | Winter. | Spring. | Summer. | Entire Year. |
|---|---|---|---|---|
| | Ins. | Ins. | Ins. | Ins. |
| Mean annual fall, . . . | 7·86 | 7·25 | 10·47 | 25·48 |
| Maximum fall; being the mean of five of the wettest years during the period, . . | 11·05 | 10·86 | 14·96 | 34·00 |
| Minimum fall; being the mean of five of the dryest years during the period, . . | 5·22 | 4·05 | 6·80 | 18·40 |

The winter column includes November, December, January, and February. The entire year column runs from January to December.

These means show the preponderance of the summer fall, and the range of maximum and minimum discharge.

The mean fall at Greenwich observatory for 43 years, was for the winters 7·86 inches, springs 7·25 inches, summers 10·47 inches, entire years 25·48 inches.

It also appears that there are very few days in the year, sometimes not over 12½, when the rainfall exceeds the average.

In this country, the rainfall varies considerably in different localities, but is usually much greater than the London gauges. On Long Island its mean is about 43·5 inches.

But all local results, in average annual rainfall, are overruled by the occasional conditions of storm flow, which in a few hours greatly exceed any ordinary circumstances, and require special provision; and it is also to be observed that such provision is largely in excess of the requirements of house sewage.

It was assumed by the London commission of 1857 that "a sufficient provision will have been made for rainfall in the urban districts, if the sewers of those districts are made capable of removing two-fifths of an inch of rain during the eight hours of maximum flow;" and in the estimate for the Metropolitan District, on the north side of the Thames, for an area of 31,556 acres, and a population taken at 74·6 per acre, or 2,355,225, the amount of sewage is placed at 16,486,575 cubic feet, while the amount of rainfall is 99,055,041 cubic feet, or about six times greater. This proportion is varied in different degrees for the additional city areas, the aggregate for a population of 3,979,089 on an area of 226,784 acres, or 17·5 per acre, being 27,853,623 cubic feet of sewage per 24 hours, and 183,059,370 cubic feet of rainfall; the highest rate of storm flow being estimated at 0·867 inches per 24 hours, the lowest 0·022, and the average 0·222 inch.

Observations given by Mr. Roe in the London Report of 1852, show that, "a rainfall of half an inch in three hours, took 12 hours in discharge, that is to say, 12 hours elapsed from the commencement of the rain before the flow of the sewer resumed its ordinary level. In a second case, a rainfall of 1·11 inches in about an hour, with an addition of 0·33 inch in the next two hours, being nearly an inch and a half in three hours, occupied in discharge 15¾ hours from the commencent of the rain."

On the basis of a fall of one inch per hour, from experimental observations extending over several years time and a large portion of London, a table was calculated for main trunk sewers from 24 to 144 inches diameter; and another, for intermediate drains, from 3 to 18 inches, on the basis of two inches rainfall per hour.

For the arrangement of the Brooklyn system, the former basis was assumed by Mr. Adams, observation having shown that in a period of seven years, but three days occur in which the rainfall in *four* hours is as high as one inch, and but three days in which the whole rain during *twenty-four* hours, was as much as two inches. It may be safely assumed from theoretical and practical deductions, that this basis is abundantly large in this country.

*Summary.*—As a summary of this sketch of the subdivision of sewage matter, we observe that so far as proportions of outlets are concerned, the provision for storm water controls and absorbs all other accumulations, leaving the most ample margin for ordinary daily flow;

while it is also evident that the correct action of the outlets is more directly dependent on ordinary flow, and should control the arrangement of the sewers as to details of form, line, and grade. While there must be sufficient discharging area for the occasional flood, the several parts must be adapted to the best discharge of the ordinary flow, so as to prevent stoppages and deposits.

On the basis of a continuous discharge from a given drainage area of one inch rainfall per hour, the flow per acre would be 3630 cubic feet per hour, or 1·008 cubic feet per second; and a 12 inch pipe with a grade of 88 feet per mile, or 1 in 60, would free 5·74 acres at this rate.

But, as seen from the experiments noted, all severe rain-storms are limited in duration, and in consequence of the several obstacles presented by any drainage surface to free flow, the sewers can never be required to remove the rainfall during the storm, but only a certain proportion of it. This proportion has been made a subject of careful experiment, and from observations extending over a period of twenty years in London, the following Table has been formed for trunk sewers to discharge one inch rainfall per hour.

*Area in acres, drained under a storm fall of one inch per hour.*

| Diameters in Inches. | 24 | 30 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 |
|---|---|---|---|---|---|---|---|---|---|---|
| Inclinations. | | | | | | | | | | |
| Level, . | 38¾ | 67½ | 120 | 277 | 570 | 1020 | 1725 | 2850 | 4125 | 5825 |
| 1 in 480 | 43 | 75 | 135 | 308 | 630 | 1117 | 1925 | 3025 | 4425 | 6250 |
| 1 " 240 | 50 | 87 | 155 | 355 | 735 | 1318 | 2225 | 3500 | 5100 | 7175 |
| 1 " 160 | 63 | 113 | 203 | 460 | 950 | 1692 | 2875 | 4500 | 6575 | 9250 |
| 1 " 120 | 78 | 143 | 257 | 590 | 1200 | 2180 | 3700 | 5825 | 7850 | 11050 |
| 1 " 80 | 90 | 165 | 295 | 670 | 1385 | 2486 | 4225 | 6625 | | |
| 1 " 60 | 115 | 182 | 318 | 730 | 1500 | 2675 | 4550 | 7125 | | |

This Table includes house drainage.

To provide for some contingencies by which trunk sewers are less easily affected, a basis of two inches storm-fall per hour was assumed for the intermediate tubular system of sewers, in arranging the following Table:

*Area in acres, drained under a storm fall of two inches per hour.*

| Diameters in Inches. | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 12 | 15 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|
| Inclinations. | | | | | | | | | | |
| 1 in 240 | . | . | . | . | . | . | . | . | 5·8 | 10 |
| 1 " 120 | ·125 | ·25 | . | . | 1·2 | 1·5 | 2·1 | 4·5 | 7·8 | 17 |
| 1 " 80 | . | . | ·5 | . | . | 1·8 | 2·5 | 5·3 | 9 | 19·9 |
| 1 " 60 | . | . | ·6 | 1 | 1·5 | 2·1 | 2·75 | 5·8 | 10 | . |
| 1 " 40 | . | 7-16 | . | 1·2 | . | . | . | . | . | . |
| 1 " 30 | . | ·5 | . | . | . | . | . | . | . | . |
| 1 " 20 | ·25 | ·6 | 1 | 1·5 | . | . | . | . | . | . |

If we take the storm-fall of the Table, discharging itself in four

times the duration of the storm, to test the tubular capacity with the known laws of uniform discharge, in the case of the 18 inch pipe, with a grade of 1 in 80, the area of 19·9 acres taken instead of 27·6, gives the estimated flow at 72 per cent. of results by formulæ which are reliable.

We have here, then, in a comprehensive view, the provisions suggested for *quantities* of rainfall, house-sewage, and street dirt, as to grades and capacities of intermediate and trunk sewers, which may be applied to the local conditions of any city system.

(To be Continued.)

---

## *On the Construction of Wrought Iron Lattice Girders.*

By Thomas Cargill, C. E.

(Continued from page 163.)

From the Lond. Civ. Eng. and Arch. Journal, March, 1863.

From what has been already said respecting the strains on any part of the web of a lattice girder, it is apparent that the total strain under a uniform load upon any one of a pair of diagonals is equal to the difference of the sums of a number of strains both compressive and tensile; or putting it in the simplest form, the total strain may be stated to be equal to the difference of two strains. These two strains will be tensile and compressive, and according as the one or the other is greater, so is the character of the resulting total strain determined. If $s_1$ and $s_2$ be respectively the compressive and tensile strains upon any diagonal, the total strain under a uniform load for a bar in compression will equal $s=s_1-s_2$: similarly, for a bar in tension $s=s_2-s_1$: but, to avoid confusion, we will limit ourselves to the consideration of a diagonal under the former strain, bearing in mind that the same principle applies equally to both, and that the only difference lies in the nature of the strain so induced. The maximum strain on any part of the web takes place, as before explained, not when the girder is under a uniform load, but when under the partial distribution of the same load which is considered under other circumstances as uniformly distributed. As it is only the movable portion of the load whose position and resulting strains can be varied, the weight of the girder and superstructure, &c., remaining constant in all cases, we might, in deducing the value of the maximum strain on the web, omit this portion from the equation, and add it afterwards as a separate item; but as we have hitherto taken them together, and given a definite value to them for girders between certain limits of span, the same course will be adhered to in future.

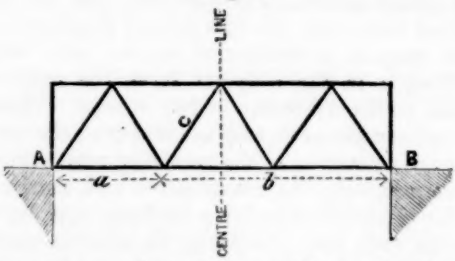
Let us first take the case of the diagonal C, in fig. 1, which represents the skeleton elevation of a lattice girder with one series of triangles introduced, the remainder of the diagram being self-explanatory. The diagonal C is acted upon by compressive strains resulting from that portion of the weight lying between it and the centre line E F of the girder, and to a tensile strain from the portion resting between it and the abutment at A, the actual strain upon it being the difference

of the two. It has been necessary here, for the sake of the following investigation, to recapitulate a little of what was said in the last paper on the subject. Let the diagonal C divide the girder into segments $a$ and $b$, and suppose the movable load to be distributed only over the larger segment $b$, the tensile strains are thus removed, or, what is the same thing, they are added to the value already obtained for the strain upon C when under a uniform load. Our expression for the strain upon any diagonal of a double lattice girder, confining ourselves to the simple case of one series of triangles, is

$$S = W\frac{(L-2a)}{4\times L}\times \operatorname{cosec}\theta.$$

In this equation for S, the value of the quantity $S_2$ has been deducted, as it had a negative tendency when the load was uniformly distributed: the portion of the load between C and the abutment however being now removed, this negative tendency is also removed, and therefore to obtain the maximum strain on the diagonal C when the load

Fig. 1.




covers the larger segment $b$, we have, putting $S_1$ for the maximum load, and S, $S_2$ as before, $S_1 = S + S_2$. As $S_2$ consists of two parts, viz: the dead and the live loads, of which the latter only is partially removed, let $w$ and $w_1$ be the total dead and live loads, and for the strain under a uniform load

$$S = \frac{(w+w_1)(L-2a)}{2L}\times \operatorname{cosec}\theta.$$

Of this equation, the part

$$w\frac{(L-2a)\times \operatorname{cosec}\theta}{2L}$$

and which contains part of $S_2$, is a constant, and it only remains to find a value for the remaining part in order to obtain a formula suitable for calculation.

In the equation $S_1 = S + S_2$, it will be seen on reference to the figure that the valuable part of $S_2$ will be the strain resulting from that portion of the live weight uniformly distributed over the segment $a$, and which is transferred to the abutment at B; employing our usual notation, this will be equal to

$$\frac{w_1}{L}\times a\times\frac{a}{2\times L}$$ for we may suppose the strains to act along every part of the segment $a$, and consequently their result-

ant will act at a distance $\frac{a}{2}$, so we have for the maximum strain

$$s_1 = s + \left( w_1 \frac{(L-2a)}{2L} + \frac{w_1 \times a^2}{2L^2} \right) \text{cosec } \theta,$$

which gives us $s_1 = s + \left( \frac{w_1}{2L}(L-2a) + \frac{a^2}{L} \right) \text{cosec } \theta;$

and reducing out, we have

$$s_1 = s + \frac{w_1}{2L^2}(L-a)^2 \times \text{cosec } \theta.$$

Substituting for $s$ its value $w \frac{(L-2a)}{2L}$ cosec $\theta$, which, as before mentioned, contains the constant part of $s_2$, we finally obtain

$$s_1 = \left( w \frac{(L-2a)}{2L} + \frac{w_1}{2L^2}(L-a)^2 \right) \times \text{cosec } \theta \quad . \quad 1.$$

If in the above equation we make $a=0$, we find

$$s_1 = \left( \frac{w}{2} + \frac{w_1}{2} \right) \text{cosec } \theta,$$

which corresponds with what has been previously stated respecting the condition of maximum strain on the last diagonal of the web—viz: that like the booms it receives its maximum strain when the girder is under a uniform load.

Putting $a = \frac{l}{2}$, we have $s_1 = \frac{w_1}{8}$, the first part of the equation disappearing.

We thus see that the strains on the web under a uniform load are a minimum at the centre, and a maximum at the same point with a load covering only half the girder. In small bridges, where the ratio of $w$ to $w_1$ is small, the first portion of equation (1) may be neglected, and the formula becomes

$$s_1 = \frac{w_1}{2L^2}(L-a)^2 \times \text{cosec } \theta.$$

In large bridges, where the reverse proportion takes place, we may put $W = w + w_1$, and write the equation

$$s^2 = \frac{W}{2L^1}(L-a)^2 \times \text{cosec } \theta.$$

This gives the strain rather greater than it really is, for it increases $w$ in the proportion of

$$L-2a : \frac{(L-a)^2}{L}, \text{ or as } 1 : 1 + \frac{a^2}{L},$$

but as the difference is on the safe side, it is of no consequence in comparison with the advantage obtained for ready calculation. It should

be understood that the error thus involved increases with the distance from the abutment, and at the centre would amount to $\frac{w}{16}$ for any one of the central diagonals; for this particular instance, however, every facility is afforded by the equation $s_1 = \frac{w_1}{8}$. For a double lattice girder with N series of triangles, we should have for the maximum strain in any diagonal under a partial load

$$s_1 = \frac{W}{4 L^2 \times N} (L - a)^2 \times \text{cosec } \theta,$$

and for the class of which $D = \frac{L}{12}$

$$s_1 = \frac{3 (L - a)^2}{8 L \times N} \times \text{cosec } \theta.$$

In the majority of cases which occur in practice, it is unnecessary to take into account the consideration of the conditions of a maximum strain on the web; if the girder be designed for a uniformly distributed load it will be sufficient, for the reason that it is only at or near the centre that any considerable difference between the maximum strain and that resulting from a uniform load occurs, and the bars there are of necessity much stronger than what is required by the latter strains, which at the centre have been shown to be equal to zero. Moreover, except in extreme instances, the slight excess of the one strain over the other which is provided for by calculation, will be amply covered by the extra strength afforded, wherever the same constant, as is generally the case, is used for both the flanches and the webs. In girders of large span it would be advisable to make one or two calculations for the strains brought upon the diagonals near the centre by a partial load, and if they were found to be of sufficient strength, as previously determined for the strains under a uniform load, it would be superfluous to carry the calculation further for those nearer the abutments. In determining the quantity of material requisite for the web, for the sake of uniformity, the same constant will be taken as was used when treating of the strains on the booms. Let s = the net section required at any part of the web at a distance $a$ from the abutment, N = the number of series of triangles, $c$ the value of the constant, and the rest of the notation as before; then for a double lattice

$$s = \frac{W (L - 2a)}{4 L \times N \times C} \times \text{cosec } \theta,$$

which becomes for our particular class of girders, by substituting for W and C their respective values $\frac{3}{5}$ L, and 4 . 5,

$$s = \frac{(L - 2a)}{12 \times N} \times \text{cosec } \theta.$$

At the abutment, where $a=0$, we have

$$S=\frac{W}{4\times N\times C}\times \operatorname{cosec}\theta,$$

and by similar substitution we find

$$S=\frac{L}{12\times N}\times \operatorname{cosec}\theta.$$

Making $L=12D$ as usual, the equation becomes

$$S=\frac{D\times \operatorname{cosec}\theta}{N}$$

As the length of all the diagonals of the web will be the same, excepting a very few which have their termination over the bearings of the girder, and concerning whose area it is unnecessary to make any calculation, as they are always made of the same scantling as the last long diagonal, if we make $l$=the full length of any diagonal, we shall have the formula for the net section required for any of the end bars, or those which terminate on the plate or pillar immediately over the abutment equal to $S=\frac{l}{N}$.

At the centre of the girder there is no strain on the web, resulting from the action of the dead weight, but a maximum strain due to the live weight when distributed over half the span, which is equal to $\frac{W_1}{8}$. In a double web with N series of triangles, putting S for the value of the strain, we shall have $S=\frac{W_1}{16\times N}$ for the strain on the diagonals at the centre: substituting for $W_1$ its value, we find $S=\frac{L}{16\times N}$.

To take an example. Let $L=160$, $N=3$, and $S=3{\cdot}3$ tons, or, making $A$=area required, we have $A=\frac{L}{72\times N}$. No tension bar in a girder of the above mentioned span should be less than 3 inches by $\frac{1}{2}$ inch, and this is fining down the material rather too much, so that in designing girders within our present limits there is practically no necessity for calculating for the strains produced by a variable weight, provided the strength of the web is determined upon the supposition that both the live and dead weights are uniformly distributed over the girder. Making $L=12\times D$, we make the value of $A=\frac{D}{6\times N}$. The actual quantity of material required for the web will vary accordingly as the diagonals are struts or ties; in the latter the number of the rivets inserted in the bar along the same line of fracture, or what would amount to the same, in the breadth of the bar, would materially affect its strength, and consequently their area must be deducted in order to obtain the net section of the bar. It is different with respect to the struts, and it depends a good deal upon the manner in which they

are attached to the flanches. Suppose the struts to be of channel iron, if they are riveted to the flanches in a manner so that their form is preserved unaltered, there is no necessity for deducting the area of the rivet holes at their junction; if, however, their webs are cut off, and they are riveted in between the angle irons of the flanches, it would be well to deduct the area of the rivet holes, as they would tend to compensate for the section lost by this method of attachment.

The same remark applies also to the use of either T or angle iron for struts, wherever a similar method is employed for joining them to the flanches. It is evident that, as it is the net section that is relied upon to give the requisite degree of strength, wherever the diagonal attains to its gross section there is a waste of metal incurred equal to the difference of the two sections; such occurrences as these are perfectly unavoidable in practice; in both the webs and other portions of the girder some part is sure to be sacrificed to the other, and it only remains to equalize the two sections as much as possible. It is maintained, and it has been partly borne out by experiment, that those portions of a girder which are under compression are not affected by the existence of rivet holes, provided that the rivets entirely fill up the holes in which they are inserted. This statement, although nearly universally received and acted upon, is only true under certain conditions, which in general are only partially fulfilled; if the holes be *drilled* and completely filled up, their insertion under the above conditions has no effect upon the strength of that particular part; where hand riveting is employed, and where there are only two or at the most three thicknesses of iron to be joined together, the holes may be considered to be filled up by the rivets, as the shortness of the rivets will enable the workmen to make a good job of it; but where, as is frequently the case, there are five or six thicknesses of plates to be riveted together, it is only by the use of steam riveting that this effect is accomplished. The drilling of holes, instead of punching them, is of comparatively modern introduction, and although there are not wanting instances where it has been employed in bridges designed for this country and for abroad, yet its application has been very limited, punching being still the method in general use.

No plate or bar of a thickness exceeding one-quarter of an inch can have holes punched in it without detriment to the material, and the greater the number, and the nearer they are to one another the greater the injury to the substance. In plates varying from one-quarter to three-quarters of an inch in thickness, where five or six rivet holes are punched to the square foot, there is no doubt that, notwithstanding the employment of machine riveting, the strength of the plate is considerably diminished. The filling up of the holes, no matter how perfectly accomplished, does not remove the injury done to the surrounding fibres of the metal by the violent blow of the punch, which accomplishes its purpose solely by main force. These two conditions, viz: the drilling of the holes, and their subsequent filling up by the inserted rivets, should be fully carried out in all cases where the net and gross sections of any portions of the girders are taken equal to each other,

and especially in the flanches, where the rivet holes are both numerous and continuous. The former of these conditions is quite as necessary, if not more so, than the latter, for the injury occasioned by the non-fulfilment of the one is negative, while that effected by the punch is positive and if excessive would altogether obviate any advantage which might be derived even from machine riveting.

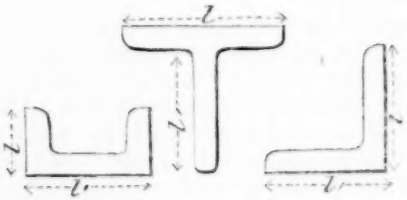
We will now pass on to consider the forms of iron usually rolled which are best adapted for the two descriptions of diagonals which compose the web of a lattice girder. We may dismiss the subject of the ties, as they nearly invariably may consist of a plain bar section; in girders designed to carry a very large variable load, it might sometimes be advisable to substitute a different form for some of the diagonals near the centre, as they are in a state of compression as well as of tension during the various positions of the load; the number of series of triangles introduced, and the lengths into which they divide the bars, will be the best guide respecting this arrangement.

The three principal forms of iron suitable for the compression bars of the web are the sections known as channel, T, and angle iron, and we will proceed to examine their respective merits for this purpose. The H section offers such serious impediments to riveting it to any other part of the structure, that it is only of use as a long pillar not intersected by any other diagonal, and consequently unsuited to form a portion of the web.

In fig. 2 are represented sections of the three forms of iron mentioned above; and directing our attention first to the T iron, and making $t$ the thickness, we shall have for its area $A=(l+l_1)t$. A very common form of T iron is one in which $l=l_1$ and $A=2lt$; taking A as the net area and $n$ the number of rivet holes in the table portion, and $d$ their diameter, we have $A=(l+l_1-nd)t$. The position of the rib or tongue of the T iron occurring exactly in the centre of the table portion of it, gives it an advantage in point of stiffness over the two other forms, but this is counterbalanced on the other hand by the fact that, in attaching it at the crossings, there must of necessity, at every one of its intersections with the other bars, be two rivets employed, one on each side of the rib, whether they are required or otherwise. As the tie iron is in compression, this may or may not, according to the judgment of the designer, affect the section necessary for the strut, but it will reduce that of the tie crossing it. In the web of any lattice girder the rivets could not be less than $\frac{3}{4}$-inch in diameter, and consequently wherever only one rivet is required there is a loss of metal incurred equal to $\frac{3}{4}$-inch along the line of fracture. In girders of moderate dimensions, one rivet is generally all that is requisite at any of the intersections of the ties and struts, and therefore it is a matter of opinion whether this loss of material is compensated for by other advantages belonging to this form of iron. In T irons also, of dimensions such that the width of the table is less than 4 inches, it follows from the very fact of the section available for riveting being divided by the rib, that there is never a sufficient amount of metal left outside the rivet hole, even should the hole be bored in a manner so that

the head of the rivet when inserted should come right up against the rib; if this were done the maximum amount of margin would be obtained; but unless distinctly specified to the contrary, the holes will be found to be punched through the centre of the half of the table lying outside the rib. Moreover, the evil is not confined to the T irons, but in consequence of the intersections taking place in the centre lines or longitudinal axes of the diagonals, there is an unequal distribution of metal produced around the corresponding holes in the ties. For example, let the table of the T iron be 4 inches wide, and the bar crossing it of a similar width; with rivets $\frac{3}{4}$ of an inch in diameter, we shall have $\frac{1}{2}$ inch outside each hole and $1\frac{1}{2}$ inches between them, supposing the rib of the T iron to be $\frac{1}{2}$ inch thick. By increasing the width of the table of the T iron, we would obtain more metal outside the rivet holes, but the same relative disproportion would still exist; by so doing we should have to increase likewise the breadth of the diagonal crossing it, which could only be done within narrow limits, unless the thickness were also increased, which would make the bar too strong: it is especially necessary in the web of a lattice girder, to preserve the correct ratio between the thickness and breadth of the bars, as any undue excess in the latter tends to affect the most important point in the web—viz: its rigidity.

Fig. 2.




To pass on to one of the other forms, viz: channel iron (see fig. 2) —making $t$ the thickness of the flanches, and $t_1$ that of the channel part $l_1$, we find for its area, $A = l_1 t_1 + 2(l - t_1) \times t$, if the thickness be uniform, $A = [l_1 + 2(l - t)]t$. A form of channel iron frequently met with is one in which $l = \frac{l_1}{2}$, in which case $A = 2t(l_1 - t)$; this section is the best proportioned as far as stiffness is concerned.

It may be remarked of channel iron that it is of more recent introduction than either of the other two forms, and that in large girders, where a considerable section of strut is required, it presents decided advantages over them. In the webs of some lattice girders constructed before this form of iron came into use, the necessary amount of section for some of the struts was obtained by riveting two angle irons together throughout their whole length; by the employment of channel iron in such instances we should avoid a great waste of labor and workmanship, to say nothing of the saving of material, and the advantage of having the diagonal all in one piece; this latter is a very

important desideratum, as the best and most careful workmanship can never make a constructed section of iron equal in strength to the same section rolled from the bloom. This has been determined by experiment, the ratio being as 1 to between $\frac{2}{3}$ and $\frac{3}{4}$. The sections of channel iron usually rolled offer no facilities for joining them at right angles to another piece of iron, the channel being the only place where rivets should be inserted; wherever the circumstances of the case required it, and warranted the extra expense of having larger sections specially rolled, rivets might be put in the flanches; but for this particular purpose channel iron is inferior to both T and angle iron. Whenever it is desirable to increase the thickness of the flanches (lettered $l, l$ in fig. 2), recourse must be had to a different section, as the thickness of the channel $l_1$ is the only part capable of variation with the same rollers.

The value for the area of an angle iron has been given before, but it may be well to repeat it here; employing the notation shown in fig. 2, and making $t$=the thickness of the two flanches, we have

$$A=(l+l_1-t)t\text{; for equal sided angle irons } A=(2l-t)t.$$

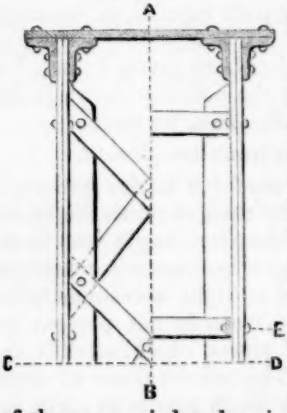
A common form of this iron, and one very useful in lattice girders, is when one side exceeds the other in length by their common thickness, or in which $l=l_1-t$, for this form we have $A=2lt$. Angle iron is the best form for the struts of small bridges, as it possesses a considerable degree of stiffness, and can be obtained of light scantlings suitable for small bars; the smaller sized angle irons do not present the same difficulty respecting the insertion of rivets which attends the other forms, particularly that of T iron. The principal use of angle iron is to attach portions of a girder which lie in planes at right angles to one another, as exemplified in the case of the flanches and webs; it is peculiarly well adapted for this purpose, from the facility with which it takes rivets in both of its sides; as it is also the form of iron most generally used in every description of ironwork, it can be readily obtained of nearly any section required without the expense of having it specially rolled. When an angle iron has rivets inserted in both its flanches, care should be taken to avoid placing them in the same line, unless the angle iron is of a sufficiently large scantling to leave a good margin of metal between each rivet hole and the junction of the flanches at the angle; as a rule it would be better to place them otherwise in every instance. The most useful angle irons have their flanches at right angles to one another, but they are also rolled with the sides inclined at other angles. If it were required to substitute a T or channel iron strut for one of angle iron having the same area, we have for the T iron $2l_1t=2lt$, keeping the thickness constant $l_1=l$, or the length of the tongue of the T iron equal the short side of the angle iron; for the channel iron we equate $2t(l_1-t)=2lt$, from which $l_1=l+t$, or the length of the channel portion equal the long side of the angle iron. In small sections these three forms would be nearly equal in strength, but in the larger the angle iron is considerably weaker than the other two.

There is another form of iron, viz: the Z section, which, although

but rarely used, might be employed with advantage in some instances, as it possesses the same faculties for smelting as angle iron. In large girders, where the breadth of the flanches would be considerable, a very stiff web might be constructed by employing this form of iron for the struts, and having double ties crossing them. This treble arrangement would also constitute an excellent form for the web of a single lattice girder, for the ends of the **Z** bars could be forged together, without any loss of the sectional area, so that the distance between the longitudinal angle irons connecting the web and flanches need not be increased beyond what is usual.

In conclusion, it may be remarked, that channel iron has the advantage in point of appearance, and that angle iron will be found the most generally useful.

Fig. 3.




In large girders, where the breadth of the booms exceeds a certain limit, it becomes necessary to increase the stiffness of the web by connecting the double lattices of the same girder together at certain points; the frequency of the connexions will depend on the breadth of the girder, and also in some degree upon the number of series of triangles in the web. Fig. 3 represents a half section of a double lattice girder, divided vertically by the line A B. The part to the left of the line A B shows an ordinary method of joining the two sides of the same girder, by riveting short lengths of bar iron to the opposite compression bars, and intersecting them by similar pieces in the centre of the section; thus converting each pair of opposite compression bars into a small lattice beam. **T** iron is the form shown for the compression bars in the figure, the small diagonals being riveted through their ribs: angle iron might also be substituted, but not channel iron, for reasons already given. Another and more simple method of effecting the same object is shown in the half section to the right of the line A B; this method consists of joining the opposite crossings of the ties and struts by pieces of bar or angle iron, and is well adapted for girders where the breadth is not more than 2 feet; it can also be applied to any form of strut, as the bars instead of being riveted to the ribs or projecting flanches of the struts, can be bent over and riveted directly to the crossing by the same rivet which joins the ties and struts of the web together. This arrangement is shown at E, and is imperative when the struts are of channel iron; whenever this method is used, of whatever form the struts may be, it will be better to rivet the crossing bars as shown at E, as we thereby avoid making more holes than necessary in the web. For very deep girders the former method is the most suitable, as it imparts a degree of firmness and rigidity to the web not to be obtained by any other means, but in girders of 70 or 80 feet span, where it is often employed, it is a

question whether it is not either altogether superfluous, or at the best does not compensate for the additional amount of workmanship and material it involves. It should be borne in mind that there is no object to be gained in stiffening a single girder beyond a certain point; it adds nothing to what is equally, if not more important, viz: the rigidity of the whole structure. It is far preferable to have any superfluous material disposed of in the bracing together of the whole structure, than to bestow it in imparting an unnecessary degree of stiffness to only a portion of it.

We have to consider the subject of the jointing of the different portions of a girder, and also propose to say a few words respecting the testing and deflection of lattice bridges, and the position of the load as it affects the amount of bracing requisite for the security of the structure.

(To be Continued.)

---

## *On Bridges of Large Span.*

From the London Builder, No. 1065.

On this subject the *Engineer* has some observations which may interest our readers. They run thus:—Something was said, a year ago, of M. Oudry's scheme for bridging the Straits of Messina by a single span of 1000 metres, or 3280 feet—the proposed structure being, of course, upon the suspension principle. This proposition exceeded in boldness that made a few years before, by John A. Roebling (the engineer of the Niagara Railway Suspension Bridge), to cross the river Mississippi at St. Louis by a single suspension span of half a mile. The Atlas Works, at Sheffield, were, we were confidentially informed, engaged upon the steel bars for M. Oudry's great bridge; but we, perhaps, run no risk in saying that, if these bars have left Sheffield, they have not reached Messina. The proposed bridge, we may observe, would have nearly five times the span of the great opening (676 feet) of the late Hungerford Bridge, the chains of which are now being erected over the 702 feet span at Clifton. We do not wish to attach the word "impossible" to any thing of which there is the least ground for hope in engineering, but very large suspension spans must be made upon improved principles if they are to give satisfaction. The Lambeth Bridge, with its three spans, of the moderate width of 280 feet each, does not quite satisfy us, that even with Mr. Barlow's mode of stiffening the roadway, such structures are likely to come into general favor. It is true that the wires of the cables of the Lambeth Bridge were twisted together, instead of being bound up as a bundle of straight parallel fibres, in the manner of the cables of the Freiburg and the American wire bridges: and the twist so put in has yielded under strain, the cables being thereby lengthened, by which the joints of the diagonal bracing have been thrown more or less out of the positions they were intended to occupy. So great was this stretching at first, that the stone paving originally intended to be applied to the bridge, and which had been in part placed upon the platform, was

found to be inadmissible, and wooden blocks had to be substituted. The saddles of many of the vertical suspending bars appear to have already slipped to some extent upon the cables, thereby causing chafing, which, however slight in amount, is not likely to conduce to the permanent strength of the bridge.

Tubular, plate, and lattice girders, which are, within the limits of their application, preferable to any other form of bridge, are only able to support their own weight over spans of between 1500 feet and 2000 feet, and would not be safe at more than one-third of the span at which they would thus break down. This is supposing them to be made of iron, and of about the ordinary proportionate depth. If, as would appear, we are on the eve of a vast and cheap production of steel, or "homogeneous iron," if that title be preferred, we may succeed with even wider spans. It is not certain either, that a greater relative depth of girder or truss might not be adopted with advantage. In plate iron this cannot, perhaps, well be done, especially when the great quantity of material then required for stiffening, or to resist buckling, is considered. There is a depth, for every truss or girder, in which the strength is a maximum for a given quantity of material; supposing a prescribed arrangement of the material in the sides, as the plate form, lattice, &c. The deeper the girder or truss, the less the strain and necessary metal in the top and bottom chords, and the greater the quantity of material in the sides. If the strains between the top and bottom flanches are taken on hollow wrought iron columns and tension bars, a deep truss may be made of large span with considerable economy of material. We have no very large spans to refer to in illustration, but the principle is the same in moderate spans. Thus in a paper lately read before the Institution of Civil Engineers, two bridges, a truss and a plate girder, were described. The dimensions, strains, weights, &c., may be given as follows:

| | Truss. | Plate. |
|---|---|---|
| Span, | 125 feet. | 86 ft. 10 in. |
| Depth, | 23 " | 7 " 6 " |
| Weight per lineal foot of each girder for single line, | 5 cwt. | 3½ cwt. |
| Maximum strain produced by a live load of 3000 pounds per lineal foot of both girders, | 3½ tons tension.<br>4½ " comp'n | 6 tons.<br>5½ " |

In the plate girder the web varied from $\frac{3}{8}$th inch to $\frac{7}{16}$th inch in thickness, while the angle irons and butt strips would, if spread out over the whole surface of the web, have amounted to more than $\frac{1}{4}$ inch of additional thickness. In the case of the truss, however, of 38 feet wider span and more than three times the depth, the whole of the parts forming the sides, or, indeed, the whole of the truss, excepting the top and bottom flanches, would not, if spread out upon a flat surface of the length and height of the truss, have amounted to as much as $\frac{1}{4}$ inch in thickness. How far open trussing could be applied with

advantage to trusses 60 feet deep, and corresponding to, say 600 feet span, would be seen on trial. For such a span a depth of 60 feet would of course require but two-thirds as much iron in the top and bottom flanches or cells as would be required for a truss of the same span and only 40 feet deep, corresponding to $\frac{1}{15}$th the span. In trusses or girders over 25 feet in depth, and where trains are to run upon the level of the bottom flanch, the sides can be braced one from the other, with a comparatively small quantity of iron. This is done in the large railway lattice bridge—six spans of 397 feet each—over the Vistula. It is one of the advantages of the lattice system that it can be made of greater proportionate depth than the plate girder, without increasing the quantity of iron for a given span in the sides, and with a corresponding saving of iron in the top and bottom flanches. In other words, the lattice can be applied to wider spans than the plate girder for a given strain per unit of section. The late Captain Moorsom, it will be recollected, designed a railway bridge with two lattice spans of 600 feet each, for crossing the Rhine, at Cologne. This bridge received the prize from the Prussian Government, and the strains per unit of section were, we believe, very moderate.

---

*The Charing Cross Bridge.* By HARRISON HAYTER, M. Inst. C. E.

From the London Civil Engineer and Architect's Journal, July, 1863.

It was stated that this bridge consisted of nine spans—six of 154 ft., and three of 100 feet—the centre opening of the Hungerford Suspension Bridge having been divided into four spans each of 154 feet, that on the Surrey side into two spans also of 154 feet each, and the opening on the Middlesex side into three spans each of 100 feet—the superstructure over the latter being fan-shaped. The width of the river at the site of the bridge was 1350 feet. The greatest depth of water between the two brick piers of the original bridge was 13 feet below low-water spring tides, and the average depth was about 9 ft.: the rise of spring tides being 17½ feet. The level of the rails was 31 feet above Trinity high water mark, and there was a clear minimum headway under the bridge of 25 feet above the same datum.

The superstructure was carried by cylinders sunk into the bed of the river, and by the piers and abutments of the suspension bridge, the abutments having been considerably lengthened. The cylinders, excepting at the fan end, were 14 feet diameter below the surface of the ground, and 10 feet diameter above, the junction between the two sizes being effected by a conical length. There were four piers formed of these cylinders, each consisting of two cylinders, 49 ft. 4 ins. apart from centre to centre. They were of cast iron, 1⅛ inch in thickness throughout, and the circumference was divided into segments, with interior flanches round all the edges, through which the segments were bolted together; and a horizontal interior rib was also cast in the middle of each segment. There were thus continual vertical lines of ribs, securing a strong columnar arrangement.

The strata through which the cylinders were sunk consisted of mud

and gravel, of varying thicknesses, overlying the London clay. The sinking was effected by excavating the material from the inside—at first by divers, but after the London clay was reached and the water was pumped out, in the ordinary way—and by weighting the cylinders to an average load of 150 tons each. These cylinders were sunk to depths of 52 feet, 62 feet, and in one case to 72 feet, below Trinity high water mark. They were filled with Portland cement concrete up to where the conical length commenced, and above with brickwork set in Portland cement mortar, to the underside of the granite bearing blocks, which were 2 ft. 6 ins. in thickness, and projected 1 inch above the top of the cylinders, in order that the weight might not come on the upper edge of the ironwork. With a view of testing the strength of the foundations, the two cylinders in the pier nearest to the Surrey side, after being completed up to the level of high water and filled with concrete and brickwork, were each weighted with 700 tons, being about equal to the greatest load they could possibly have to sustain, supposing the four lines of rails on the bridge to be loaded with locomotive engines. This caused the cylinders to sink permanently 4 inches. To bring the other cylinders to a bearing, so as to prevent any settlement after the completion of the bridge, from the weight of the permanent and moving loads, they were each weighted with 450 tons, when it was found that they permanently sank, on an average, 3 inches each. Each pair of cylinders forming a pier was connected together transversely by a wrought iron box girder, 4 feet deep, which also served as a cross-girder for supporting the roadway. Assuming the four lines of way on the bridge to be loaded with locomotive engines, the pressure on the base of the cylinders would amount to 8 tons per square foot, and on the brickwork at the top of the cone to about 9 tons per square foot.

The superstructure of each of the 154 feet openings consisted of two main girders, to the underside of which were suspended cross-girders, for carrying the roadway platform. These cross-girders extend beyond the main girders, and formed a series of cantilevers on the outer sides, for supporting two footpaths, each 7 feet wide in the clear. The main girders were of wrought iron, and were not continuous, but extended only over one opening. Each girder had to support, inclusive of its own weight, a maximum distributed load of 750 tons. The extreme depth of these girders was 14 feet, and the depth between the centres of gravity of the top and bottom members were 12 ft. 9 ins. The sides of the bearings were divided into fourteen equal parts by a pair of vertical bars, connected to the top and bottom by pins of puddled steel, 7 inches diameter at the ends of the girder, decreasing to 5 inches diameter at the centre; and each division contained a double set of two diagonals crossing each other. The top and the bottom of these girders were of boiler plate, and consisted of of horizontal tables 4 ft. and 3 ft. wide respectively, and of four vertical ribs, the two outer rows being 24 inches deep, and the two inner rows 21 inches deep. The aggregate thickness of the plates in the horizontal table of the top in the centre of the girder was $3\frac{1}{8}$ inches, and

in the bottom $3\frac{1}{16}$ inches, without the angle irons, and of $4\frac{1}{8}$ inches and $4\frac{1}{16}$ inches respectively with the angle irons, but exclusive of the angle iron covers. It was arranged that, with the greatest load, the maximum strains should not exceed 4 tons per square inch in compression, and 5 tons per square inch in extension. All the rivet holes were drilled by machines capable of drilling several holes at one time. This plan was, under the circumstances, less costly than punching, besides which a great saving was effected in putting the work together. The diagonals acting as ties were of Howard's rolled suspension links, each separate tie being composed of two or three links, as required, riveted together. The diagonals acting as struts were each in one solid forging, and were united together in pairs by zigzag bracing of wrought iron. In the centre of the girder, where the diagonals acted as both struts and ties, the pairs were united together in the two central spaces by the zigzag work. The dimensions of the struts varied from 12 inches by 3 inches at the ends to 6 inches by $2\frac{1}{2}$ inches in the middle, and of the ties from 12 inches by $2\frac{1}{2}$ inches at the ends to 6 inches by 2 inches in the middle. The ends of the girders over the piers were boxed in, with plates $\frac{3}{8}$-inch thick, stiffened by angle and T irons. Over the cylinders the girders rested on sheet lead, laid upon the granite blocks. On the brick piers and the Surrey abutment they rested upon roller bed-plates. The girders were put together in place on a staging, the upper and lower platforms of which were accurately adjusted to the proper camber. The whole of the plates were drilled, and the struts and ties were completed, before being sent to the works. The weight of each main girder was 190 tons. One of the main girders was tested when in its place with a distributed load of 400 tons, when the greatest deflection observed was $1\frac{5}{16}$ inch, and the permanent deflection after the load was removed was $\frac{1}{2}$ inch.

The cross-girders of the 154 feet openings were of wrought iron, and were generally similar in character to the main girders, from which they were suspended, at intervals of 11 feet apart from centre to centre. They were 4 feet deep in the middle, and 2 ft. $1\frac{1}{8}$ ins. deep where the cantilevers were united to them outside the main girders. The top and bottom consisted of two plates, 18 inches wide by $\frac{5}{8}$ inch thick, the sides being of lattice bars united to the top and bottom by angle irons. The cantilevers decreased from 2 ft. $1\frac{1}{8}$ ins. deep at their junction with the cross girders to 1 ft. 2 ins. deep at their extremities. Each cross girder, including the two cantilevers, weighed 9 tons. When two of these cross girders, without the cantilevers, were tested with a load of 140 tons, equivalent to 70 tons on each girder, the maximum deflection in the centre was 1 inch, and the permanent deflection when the load was removed was $\frac{1}{4}$ inch.

The superstructure of the three 100-feet openings of the fan end was supported by the brick pier and abutment on the Middlesex side of the suspension bridge, and intermediate to these by two rows of seven and of nine cast iron cylinders respectively. These cylinders were 10 feet diameter below the ground level, the outer ones being

8 feet diameter, and the inner ones 6 feet diameter above that level. They were sunk to depths averaging 40 feet below Trinity high water mark, and were filled with Portland cement concrete to about 5 feet above that level; but it was not considered necessary to fill in the remaining portion of these cylinders. On account of the great width of the fan end, which increased from 49 ft. 4 ins. at the brick pier to 168 feet at the abutment, the plan of supporting the roadway on cross girders, suspended from outside main girders, was inadmissible; and as it was not desirable to introduce intermediate main girders, projecting above the line of rails, the roadway was carried by interior plate girders, laid at right angles to the piers and abutment, and by the outside main girders, which were laid at the angle of inclination of the fan. The outside main girders were of the same depth, and were generally of the same character, although lighter in all the parts, and were fixed at the same level, as the girders of the 154 feet openings. The interior plate girders were of the ordinary construction, 5 feet deep, or one-twentieth of the spans, and weighed 26 tons each. The triangular spaces between the outside main girders and the outer interior plate girders were filled in with cross girders, terminated by cantilevers, projecting beyond the face girders, and similar to those outside the main girders of the 154 feet openings.

The roadway platform over the 154 feet openings consisted of planking 4 inches thick, spiked to longitudinal timbers, 15 inches by 15 inches, placed underneath the rails, and bolted to the cross girders. Over the fan end, the platform consisted of planking 6 inches thick, secured to the girders. The footpath platforms were of planking 6 inches thick.

The first cylinder of the Charing Cross Bridge was pitched on the 6th of June, 1860, and as the bridge was now on the eve of completion, its construction would thus extend over a period of about three years. The weight of wrought iron in the bridge, including the steel pins, was 4950 tons, and of cast iron 1950 tons. The total cost, including the abutments, would be £180,000, or £1 15s. per square foot, and £131 per lineal foot. The cylinders of the 154 feet openings cost complete £20 per lineal foot; the outer cylinders of the piers of the fan end cost about £12, and the inner ones about £10 per lineal foot. The bridge was designed by Mr. Hawkshaw, President Inst. C. E., the engineer to the Charing Cross Railway Company, and was carried out under his immediate supervision, Mr. John H. Stanton, M. Inst. C. E., being the resident engineer. Mr. George Wythes was the contractor for the construction of the railway, but this bridge was sublet to Messrs. Cochrane & Co., whose representative on the works was Mr. Joseph Phillips, Assoc. Inst. C. E.

Proc. Inst. Civil Eng., April 28, 1863.

---

### *American Iron Bridges.* By Zerah Colburn.

From the Lond. Civ. Eng. and Arch. Jour., July, 1863.

The great number of timber bridges in America might be accounted for from the fact that the first cost of the truss, or super-

structure, of a timber bridge of any given span, was generally less than one-half that of an iron bridge of the same strength. Iron had been occasionally employed since 1835, but only within the last ten or twelve years to any extent.

Cast iron tubular arches, including one of 80 feet span, were erected from the design of Major Delafield, about the time when similar arches were adopted, by the late M. Polonceau, in the construction of the Pont du Caroussel, over the Seine. Major Delafield's arched ribs were elliptical in section, the transverse vertical axis being about four times the length of the conjugate axis. In 1858, an aqueduct bridge was erected at Washington, by Captain Meigs, in which the two arched ribs were formed of water pipes through which the water flowed. The span of this bridge was 200 feet, the rise being 20 feet. The pipes were circular in section, 4 feet in diameter inside, and 1½ inch thick. This bridge was 28 feet wide over all, and the roadway was of timber supported on wrought iron spandrils. The bridge was tested with the arched ribs filled with water, and with a load of 125 lbs. per square foot upon the roadway, making the total weight on each rib about 350 tons. The thrust of one-half of the weight upon each abutment would be about 470 tons, corresponding to a strain of 2 tons per square inch of sectional area of iron in the pipes. This strain did not include the pressure of the water in the pipes, which were proved to 300 lbs. per square inch. These examples were, so far as the author was aware, the only iron arches yet completed in the United States; and with the exception of a few pivot bridges, and one or two ornamental bridges in the Central Park at New York, they comprised nearly all the cast iron bridges in that country.

There were a small number of plate or boiler iron bridges. The first was erected in 1847, in place of a timber bridge, by Mr. Millholland, on the Baltimore and Susquehanna (now the Northern Central) railroad. This was 50 feet span, and the two girders were each 6 feet deep, the two sides of each being formed of plates ¼ inch thick. Between the sides at the top a timber 12 inches square was bolted as a compression member, and the top was further strengthened by two wrought iron bars, 5 inches deep by ¾-inch thick, while four similar bars were riveted along the bottom of each girder. The sides were stiffened by stay-bolts, inclosed in cast iron distance pieces, 12 inches apart from centre to centre. The centre of each girder was placed exactly under the rails, which were spiked to the timber forming the compression member. The breaking strain of the pair of girders was equal to 250 tons of distributed load, and the weight of the bridge was 14 tons. When completed this bridge was coupled at each end to a railway wagon, and was slung by chains to a temporary timber truss. It was then taken 19 miles by railway, run exactly over the place it was intended to occupy, the existing timber bridge was cut away, and the girder bridge lowered with the permanent way ready for traffic, the whole operation not having caused an interruption of more than two hours.

Having been long accustomed to trussed timber bridges, American

engineers, in adopting iron, naturally employed it in trusses also. But before describing the various forms of iron truss bridges, the strength of American iron was referred to. It appeared from a vast number of experiments made by the United States Ordnance Board, that there was but little iron in any American cast guns of a less tensile strength than 11 tons per square inch, and in 1851 the author had himself seen portions cut from 11-inch guns, weighing 6 tons 15 cwt., tested up to 16·14 tons. The transverse breaking strength of a large number of samples of re-melted iron, when reduced to the English standard of a bar 2 inches deep and 1 inch wide, resting on supports 3 feet apart, varied from 27¾ cwt., to 48·1 cwt., the general strength being 34 cwt. The minimum crushing strength of the irons experimented upon was 37¾ tons, and the maximum 77¾ tons. Experiments made by the Franklin Institute twenty-five years ago, showed the mean tensile strength of cast iron at the first melting to be 9⅓ tons; and the iron now employed by engineers in Philadelphia bore from 7·14 tons to 10·2 tons. In 1858, Mr. Albert Fink tested the iron used in the construction of a large bridge on the Louisville and Nashville Railroad. When the results were reduced to bars 2 inches deep by 1 inch wide, on supports 3 feet apart, the minimum breaking weight was 29½ cwt., mean 32·68 cwt., maximum 39 cwt. This iron was a mixture of two-fifths cold blast, two-fifths hot blast, and one-fifth scrap.

With regard to wrought iron, the experiments made by the United States Board of Ordnance gave a tensile strength varying from 17 tons to 33·3 tons per square inch; and those of the Franklin Institute a mean strength of 26 tons for plate iron. At the present time 27 tons was generally expected of American boiler plate. Other experiments were also quoted to the same effect, and it was remarked, that from what had been stated, American engineers might work up to rather higher strains than were commonly allowed in this country. The high qualities of the best American iron were due to the purity of the ore and of the fuel employed in the manufacture. In bridges of less than 150 feet span, even when loaded with a weight of 1·34 tons per lineal foot of single line, the strains did not exceed 3·57 tons per square inch on wrought iron in tension, and 4·46 tons per square inch on cast iron in compression.

Of the iron truss bridges that were described, all had certain peculiarities in common, distinguishing them from the trussed structures adopted in this country. In almost every case the compression members of American iron trussed bridges were of cast iron cylindrical or octagonal pipes. These simply abutted end to end against each other; and, although means were employed to prevent lateral motion of the ends, flanches and bolts were never introduced for that purpose. Another and one of the most important peculiarities was the depth of truss, a depth exceeding that employed by English engineers, except in rare instances, as at Chepstow and at Londonderry. American engineers considered a depth of one-eighth for spans of 200 feet as only moderate; for shorter spans depths of one-seventh and one-sixth were common; and in the case of one bridge of 120 feet clear span, the depth

was 23 feet, or nearly one-fifth of the span. It should, however, be observed that in some of the American trusses the arrangement of the tension members were such, that if the depth of the truss were not considerable, the diagonals would be inclined at hardly more than 8° or 10° from the horizontal; in which case a very large quantity of material would be employed in proportion to the supporting power obtained. No American iron or timber bridges were ballasted; nor had they any floor, only a foot-path of planks. In bridges having the rails at or above the level of the top chords, known in the States as deck bridges, parapets were seldom employed, and the trusses were often so short a distance apart, that a passenger on looking out of a carriage window was unable to discover any support beneath the train. In no bridges of two or more spans were the trusses made continuous over a pier; each span being always treated as a bridge by itself.

One of the earliest iron trusses adopted in the States was a trellis known as Rider's Bridge. Cast iron T or angle irons were employed in compression, and wrought iron bars in tension. These bridges were so slightly proportioned that they occasionally broke down, and the author was not aware that the plan was not adopted in new structures.

A detailed description was then given of a Murphy-Whipple bridge, having a span of 125 feet, with the railway supported on the lower chords. It was for a double line, and there were three trusses, 14 ft. apart from centre to centre, the strength of the middle one being about one-half greater than that of either of the others. The trusses were 23 feet deep, or 0·14 of the span. The top chord was formed of cylindrical cast iron pipes, and the bottom chord of a chain of square bars, 10 ft. 5 ins. in length between the centres of the eyes. Upright cast iron posts, placed at the same distances apart, divided the truss into panels, and as the posts were in two lengths, they were each trussed by four round rods, to prevent lateral failure. The diagonals were in pairs of square rods, and were formed also as eye-bars grasping pins 2½ inches diameter in the top chord, where the pipes abutted upon each other, and pins 3½ inches diameter in the bottom chord, thus connecting the links or bars of which it was composed. The diagonal tension bars only crossed each other in two panels on each side of the centre of the truss. The top and bottom chords were braced horizontally, with transverse and diagonal bars. The railway bars were supported upon longitudinal timbers, which rested upon transverse wrought iron rolled beams. The total weight of the superstructure complete was 102½ tons, or 8 cwt. per foot of single line. With an additional distributed load of 3000 lbs. per lineal foot on each line, the tensile strain at the middle tension rods would be 4·27 tons per square inch in the middle truss, and 3·12 tons per square inch in the outer trusses; but with a train on a single line only the ordinary working strains did not exceed 2½ tons per square inch in tension, nor 3 tons in compression.

In 1861, an iron bridge was erected on the line of the Pennsylvania Central Railroad, across the Schuylkill at Philadelphia. It had two clear spans of 192 feet each, and one pivot span, or turning bridge,

192 feet long. The construction was similar to that just described, but the truss was only 19 feet deep. The upright posts or struts were of wrought iron, so rolled that when two bars were put together they formed an octagonal tube. The top and bottom chords of the turning bridge were of wrought iron rolled beams, so that either might resist extension or compression. The three spans for a single line contained an average of 5 cwt. of wrought iron, and 7½ cwt. of cast iron, per lineal foot. The net cost of the bridge, exclusive of masonry, was £ 8144 10s. or £ 14 4s. per lineal foot; the wrought iron costing £ 22 15s. 6d. and the cast iron £ 6 11s. 3d. per ton.

The pivot was of a kind extensively employed for turn-tables. It consisted of a fixed and a movable cast iron disk, both grooved to receive a number of steel rollers, each turned to the frustra of a double cone. A circular railway was laid around the pivot, but the wheels only bore upon it when the bridge was not truly balanced on the rollers. With a load of 14 tons balanced upon one of these bearings the whole was revolved by a weight of 3½ lbs. hung over a pulley, and connected by a cord to the periphery of the turn-table.

The form of truss introduced by Mr. Wendel Bollman was next noticed. In it the load upon each panel was transferred directly to the ends of the truss, through a pair of straight suspension bars doing duty only in that panel. With the exception of one pair of suspension bars supporting the centre of the bridge, the bars in each pair were of unequal length, and their lower ends were attached to the upper extremity of a compensating link in order to allow for contraction and expansion. This bridge could not alter its form under unequal loading. A bridge upon this plan at Harper's Ferry, on the Baltimore and Ohio Railroad, had four parallel trusses for a double line and a clear span of 124 feet. The span was divided into eight panels, and the depth of the truss was 17 feet 6 inches. The top chords were each formed of a single line of octagonal cast iron pipes, and the vertical posts were also of cast iron. The strains upon the various parts of the truss caused by the weight of the bridge and of a load of 1½ tons per lineal foot, were 2·8 tons per square inch in compression in the top chord, and varied from 4·46 tons per square inch in tension in the longer suspension bars to 7·14 tons in the shorter bars. Mr. Bollman had stated, that this bridge was tested with a moving weight of 122 tons of locomotives on one span of single line, or nearly one ton per lineal foot, and that the deflection at a speed of 8 miles an hour was 1⅜ inch at the centre.

The iron bridge designed by Mr. Albert Fink had been more extensively adopted than any other on the railways of the United States. In this bridge a pair of diagonal tension bars connected the foot of the principal strut or king-post in each truss with the ends of the top chord. This pair of diagonal bars supported one-half of the whole weight of the truss and its load. Each half span was subdivided by a strut, and two diagonal tension bars extended, one to the nearest end of the top chord, and the other to the top of the centre post. Each quarter span was again subdivided into eighths, and these again,

for spans greater than 100 feet, into sixteenths. Under the direction of Mr. B. H. Latrobe, then engineer of the Baltimore and Ohio Railroad, in 1852 Mr. Fink erected an iron bridge of three spans, each of 205 feet, where that line crossed the Monongahela river. The depth of the truss was about one-ninth of the span, and the railway was carried at a little above the level of the bottom of the truss. The weight of the bridge including the permanent way was only ½ a ton per foot of single line, and with an additional load of 1 ton per lineal foot the tensile strains upon the wrought iron did not exceed 5·15 tons per square inch, and the compression on the cast iron 4·25 tons. The Green River and the Barren River bridges were then alluded to, as being nearly identical in construction to that last described.

The Bollman and the Fink trusses for a single line and in spans of from 160 feet to 200 feet, cost £14 per lineal foot, or nearly £28 per ton; while timber bridges of the same show only cost £5 to £7 per foot. Still iron bridges now met with an amount of favor which appeared certain to insure their ultimate substitution for timber bridges. A gradual preference was being shown to the plate girder, as the great annual range of temperature, from 20° below zero to a reflected heat of 130 in the summer sun, was not favorable to the use of cast iron in structures of such importance as railway bridges.

Proc. Inst. Civ. Eng., May 5, 1863.

---

## *Bridges and Subways Across Carriage-ways.*

From the Lond. Civ. Eng. and Arch. Journal, July, 1863.

Any efficient means that can be adopted to facilitate the circulation of the traffic in the over-crowded streets of the metropolis, would be a great boon to the public. For years past the inconvenience and danger to pedestrians arising from the great carriage traffic has rapidly increased, and urgently demands the adoption of some remedial measures. The subject has recently engaged the attention of the Commissioners of Sewers of the City of London, who placed it in the hands of their engineer, Mr. Haywood, who has carefully investigated the whole subject, as well as plans submitted by Mr. Williams for forming bridges over the streets, and also by Mr. Newton for forming subways beneath the streets. Mr. Haywood's report has recently been made, and the following extracts will be found to possess interest:—

"*Bridges over Streets.*—These, as matter of construction, are perfectly practicable; the principal conditions which must be observed in their formation and maintenance are as follows:—

They must leave a clear height of 18 feet above the entire width of the carriage-way. The width that would be requisite must depend upon the traffic which might be expected to pass over them; 10 feet in the clear appears to me to be the least that should be given, for their construction could scarcely be justified unless a large usage was expected. They must be strong enough to sustain great weights and unequal loading; for they would be subject to be densely and unequally loaded. As sight-seers and idle people would congregate upon them, each bridge would require two policemen to be constantly pre-

sent to insure circulation and order. To construct inclines to arrive at the level of the bridges would clearly be an impossibility in the City, the access must therefore be by staircases. As the level of the bridges would be about 19 feet above the level of the pavement, it would require thirty-eight steps to ascend, and as many to descend them. Circular staircases, which would occupy the least room, would however occupy the room in the most inconvenient manner, if taken from the streets; indeed there are no streets of sufficient width to enable them to be formed, and they moreover are unfitted for the purpose, inasmuch as, portions of the treads being so narrow, they would inevitably lead to accidents. Staircases upon a different plan would occupy very large spaces, which spaces can in few, if in any, parts, be spared for the purpose from the footways or carriage-ways. Steps wherever placed upon the public way, assuming that they could be so placed and that the commission has the power to place them there, and whatever the mode in which they might be constructed, would be a nuisance to the inhabitants residing immediately adjacent to them, and probably would cause them pecuniary loss, for which the commission would have to pay compensation; and even if the staircases were constructed within property belonging to the commission a nuisance might be held to be caused by the bridge itself, although doubtless not in so great a degree as where there were staircases over the pathway in addition to the bridge. The difficulty of finding room for staircases could be obviated by taking houses upon either side of the street, and making within side of them staircases from the ground level up to the level of the bridges. Ample staircase room could be got by such a mode; but at the spots where these crossings would be most useful the property is of a most valuable nature, and the cost of the bridges with such approaches would therefore be exceedingly great.

I can scarcely imagine that any bridge across a metropolitan thoroughfare can be otherwise than detrimental to its appearance, and as these bridges are principally required across the most important, widest, and handsomest streets, there is but little doubt that they would be eminently detrimental to them; but there is no reason why such bridges should be in themselves ugly, or in any respect like the hideous railway bridges now spanning the streets, which are designed with great disregard to appearance, and almost in defiance either of architectural rule or of the commonest taste; they may indeed be pronounced, in respect of appearance, as a disgrace to the metropolis.

These are some of the difficulties appertaining to the bridges, and I will now proceed to the consideration of the alternative mode.

*Subways beneath Streets.*—Making allowance for the depth requisite for the paving stones, pavement bed, pipes, and thickness of the arch or covering of the subway, about 5 ft. 6 ins. must be allowed from the surface to the underside or soffit of the covering; to this 8 feet at the least should be added, making together 13 ft. 6 ins. from the surface of the street to the paving of the subways. This depth would in the majority of cases cut the sewers in halves. It is possible that in most situations they might be constructed at an increased depth, or means adopted to get over the difficulty, but it could only be at a

large cost and great public inconvenience. The depth would involve a descent and an ascent of 27 steps. They could be ventilated, but it would be with difficulty; in all cases they must be lighted by gas, and policemen must be always in them, or they would prove a nuisance, a lurking place for thieves, or the means of their escape. Upon the occasions of sudden rain the police would with difficulty be able to prevent them being used as places of shelter; indeed, it is difficult to say how it could be prevented at all, unless by closing them altogether upon such occasions by gates placed at the outlets. The difficulty of finding room for staircases is nearly if not quite as great as it would be for the bridges; but if constructed they would not be so great a nuisance to the inhabitants as the staircases to the bridges would be if they were formed upon the public ways. But ample room for staircases could be obtained (as for the bridges) by purchasing houses, and as a ground floor only would suffice for the staircase to the subways, a larger portion of the upper part of the houses would be available for other purposes.

The subways would in cost, I think, be cheaper than bridges, provided it was found that the pipage and the sewerage did not require altering to a great extent.

Upon consideration of all circumstances, it is difficult to pronounce which would be the best. The bridges would of course suggest themselves to perplexed pedestrians more than the subways, and could alone be found readily by strangers, but the number of steps to be encountered would be greater; whilst the subways, especially if reduced in size to the most economical dimensions, although offering less trouble, certainly would not invite people to go through them. On the other hand, the fewest steps would be preferable to the old and infirm, as giving the least trouble in ascending and descending. And, on the whole, I think the balance of advantage would be in favor of the subways.

There is nothing new in the principles of either of the schemes submitted, for bridges across the public ways have been frequently suggested, and have been elsewhere spoken of during the last twenty years, and subways for crossings have been suggested even more frequently. The detail of construction is another matter, but it need be but of an ordinary character when practicable situations were once decided upon."

Mr. Haywood then proceeds to an investigation of the police returns and observations of the street traffic, to aid in determining whether bridges or subways are absolutely needful, and whether, if constructed, they would be much used or would materially lessen the number of accidents; although he states that only the construction of bridges or subways would answer these questions.

In conclusion, Mr. Haywood remarks that this subject has had some attention given to it at Paris. There is no spot in London where there is more danger in crossing than at some points of the Boulevards at Paris; for the carriage-ways are there very wide, the traffic during some hours of the day very great and much quicker than in

the main streets of the City. There is ample room upon the footway for the construction of staircases, and the bridges would not therefore create annoyance; moreover, the French architects would in all probability so design the bridges as to make them but little detrimental to the appearance of that beautiful highway; neither subways or bridges however have been attempted, although some years ago a French engineer designed bridges for that purpose, to which he gave the name of *Passerelles*, one of which he proposed to construct at the junction of the Boulevards du Centre, St. Dennis, and Strasbourg.

## MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

### *Remarks on an Optical Instrument which Indicates the Relative Change of Position of two Objects which are Moving on Different Courses.*

I have read with some interest an article in your August number, taken from the *London Civil Engineer and Architect's Journal*. It treats of "an optical instrument which indicates the relative change of position of two objects which are moving on different courses."

I am at a loss how to account for the apathy and indifference with which the naval and civil marine interest of the world, have viewed from year to year the immense destruction of life and property, by collision on water, without making anything like an adequate effort of prevention. What has been done by this great interest, to prevent these fearful collisions of nearly daily occurrence? Why nothing, absolutely nothing, if we except lighting poor oil lamps, and causing them to be suspended in conspicuous places on board of vessels. This idea may have been borrowed from the untutored savage. Should not humanity and science at this advanced age blush, in not endeavoring at least to lessen the chances of collision, and make amends for their negligence in the past by diligently applying themselves in procuring some remedy for the future? To point out and show the little attention paid to this subject; nothing could be more convincing, if proof were at all necessary, than this simple, I may say, rude instrument alluded to. Every beginning is weak, and we will accept of it as the first instalment of science, to a highly charitable and truly humane object.

It strikes me that if we should attach a micrometer-telescope for measuring distances to this lantern, we would materially increase its efficiency and usefulness. Having no mechanical genius myself, I will leave this suggestion to some of your ingenious Philadelphia artisans to be carried out. But I feel assured that the combination properly made would form a good instrument, and be a real improvement.

I shall now briefly show how the micrometer may be used in preventing collisions. In a prefatory remark to the description of this lantern, the writer says: "If, however, the object be in motion—if, for example, it be a vessel proceeding on its course, then it is impos-

sible by means of trigonometry to calculate its distance from the deck of a vessel which is itself in motion." He does not by this mean, as his words would seem to imply, that the motion of the observer's vessel rendered the distance the more difficult of finding. For by his method, without this motion to get at a side, it would be impossible for him to compute the distance of the two objects asunder. It is this motion whose rate is supposed given, together with the elapsed time, that give the distance of the positions of the vessel, at the first and second observations. And it is on this data, derived from the motion of the observer's vessel, on which he must depend for finding the distance of the object in view, whether this object be stationary or moving, at a given rate on a known course.*

Instead of depending on the motion of the observer's vessel, for a given side which is only an approximation at the best, let us measure the angle that the vessel's mast, the height of which we will suppose known, makes at the eye with a good micrometer-telescope, and we get the distance with accuracy without further data, and without any reference to the motion or positions of the ships. It may be asked how will the height of the mast of an unknown vessel be known? I answer, the spars of vessels of the same class are nearly of the same height, and assuming that the spars of a first class ship, are on an average of 110 feet in height, those of second class ships 90 feet, and if we put the spars of barks, and first class brigs and schooners 70 feet, we may without material error, estimate those of smaller brigs and schooners at 50 feet.

A look through a telescope will enable us to tell to which of these classes the vessel in sight belongs, and I am convinced that an experienced seaman, can form an idea of the height of her masts to a foot. Say he comes within five feet of the height, and then he has her distance near enough for all practical purposes. Then let us have a separate table of distances, calculated for heights, commencing as low down as five feet, and increasing gradually by 5 feet, until we end in forming the table of 110 feet for each revolution of the micrometer from 40 revolutions to 1 revolution.

Thus we have always a ready reckoner at hand, which tells us immediately the distance of any vessel in view. Its use is not confined to ascertaining distances on water, we can apply it to finding distances by land also. For instance, a house appears in view, and we want to know the distance to it, we know that in most houses the heights of windows are 6½ feet. Apply your telescope to one of its windows, and count the micrometer revolutions for the value of the angle, that the height of the window subtends at the eye, and from it you derive the distance. It is a wonder to me that an instrument so generally used by surveyors, should not be universally adopted by those to whom its application would be of the utmost importance. A captain of a merchant ship when chased by a pirate, could always tell his distance. If it were the means of saving one of our ships, by

* If the distant vessel steers on an unknown course at an unknown rate, it is impossible to find her distance, even in the above; if the vessels run at the same rates, on parallel courses, it becomes impossible to find the distance.

increasing vigilance on board, from falling into the hands of these marauders, I would feel compensated for drawing your attention to its use.

How can this instrument be applied to finding distances at night, when the masts cannot be seen?

I will try to show you what I think ought to be done. Let all mariners agree to suspend lamps in a vertical direction, from the same mast in all vessels whatever may be their size, at a uniform distance apart at night. Fifteen feet would do for long ranges, but for a short distance of 1000 feet, 5 feet would be better.

Short distances cannot be measured with the micrometer for the angle, that that portion of the mast subtend at the eye is too large, and because the two lamps could not be seen through the object glass at the same time.

The lights as placed now in a horizontal plane on board vessels would not answer our purpose, except in case a vessel's broadside was directly turned to us, or she was in the act of crossing our course at right angles.

Let then a micrometer telescope be attached to the lantern described in your article, and a collision is placed beyond the reach of probability, provided, all vessels carry these lamps suspended at some agreed distance apart.

For instance, we see these lights, and find they subtend an angle of say 8 revolutions of the micrometer. After sailing ten minutes, we find they subtend an angle of 12 revolutions. Here then the distance between the vessel has decreased one-fourth. In eight minutes more I look again, and find the lights subtend an angle of 16 revolutions, therefore, the original distance between the vessels is reduced to one-half. Now that the two vessels are approaching with rapidity, I look into the lantern and find the light stationary, hence a collision seems inevitable, and I put the helm about and steer a different course to avoid it, and when the danger is past, resume my old course.

From what we have shown, it is clear that the micrometer in indicating the rapidity of approach, points out the danger of a collision, but when attached to a lantern, it becomes a perfect instrument.

---

### *Explosion of the Locomotive Atsion.*

J. Brodhead, Esq., President:

Dear Sir:—On the morning of Wednesday, 19th inst., the boiler of the engine Atsion, exploded under the following circumstances. It was attached to down mail train, consisting of 19 cars of all kinds, and had proceeded about 150 yards, being opposite the Company's house, at corner of Front and the Railroad, when the explosion occurred.

The boiler is what is usually denominated a wagon-top boiler. The cylinder part thereof was composed of three sections 35 ins. long, and a fourth of less length attached to the wagon-top.

It was the section adjoining the front one that gave way.

It overlapped the adjoining sections, both front and back, about 2 ins., being secured to them by a single row of rivets. It was composed of two sheets lapped and united in the same manner, one of the seams being situated at the top of the section, as secured in its place.

The break occurred in the sheet that underlapped at this seam, extending the entire width of the sheet, parallel with the end, and 2 ins. from it, or directly under the end of the sheet that overlapped. Giving way there, the sheets were torn from that point each way, entirely around, breaking through the holes of the rivets by which they were attached to the adjoining sections, and were thrown down upon the frames of the engine with such force as to break them off.

The sheet that first gave way, was cracked at the line above stated 26 ins. out of the 35.

Along 9 ins. in four sections varying from 1 to 3 ins. in length, the break extended entirely through the sheet. Along the remaining 17 ins. it varied in depth, extending in some places within $\frac{1}{32}$ in. of being through, the crack being on the inside of the sheet, which was $\frac{1}{4}$-in. thick.

There was no previous indication of the condition of the sheet, other than that an amount of steam and water about equal to what would escape from an ordinary leaking joint, or loose rivet, was observed escaping from under the jacket which covered the boiler, during two or three days previous to the explosion. When it first occurred the appearance of the sheet clearly indicated the above previous condition. The rush of the water and steam outwards bent the steam pipe and the outer belt of tubes about three inches outward. In the case of two or three of the tubes they were bent more, and to such an extent as to break them.

The remaining tubes do not seem to have been affected. And they hold the two parts of the boiler together, and as far as we can judge without running lines, in the exact relative position they were. In holding the two parts together, they have the assistance of two $\frac{3}{4}$-in. rods, which are attached to front flue sheet, and extend to the section back to the break, being riveted to the sheets.

The windows and doors to the house, which is about twenty feet from the track, were blown in, in some cases forcing the entire frame in, but doing no farther damage either to the house or inmates.

There were two ladies in the house, but one had just gone to the back, and one to the front, escaping the force of the explosion,—so, happily, no person was injured to even the slightest extent; and no further damage was done the engine than above indicated, other than bending guides, eccentric rods, &c., and tearing off the smoke stack.

The pressure of steam was 110 lbs.

Very respectfully, yours, &c.,

G. W. N. Custis, *Gen. Super't.*

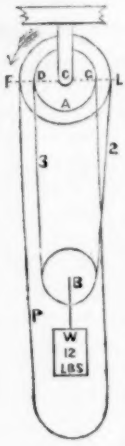
August, 1863.

## *Differential Pulley Blocks.*

From the Lond. Mechanics' Magazine, Sept., 1862.

SIR:—For your own satisfaction as to the truth of my previous note, I beg to enclose you a copy of the passage in Carpenter's "Mechanical Philosophy," which I referred to.

"An extremely simple and ingenious application to the pulley of the principle which has been mentioned under the head of the Chinese wheel and axle, has been devised by Mr. Moore, of Bristol. Its beauty consists in permitting an increase of power to any extent by the employment of only two pulleys. Its construction will be readily understood from the accompanying diagram.




A is a fixed pulley with two grooves, of which one is a little larger than the other. An endless cord passes over the larger groove from F to E, then beneath a movable pulley, B; after which it returns over the smaller groove from D to G, and hangs down, so as to become continuous with the first line. Now, if a power be applied at P, so as to draw down the line 1, the line 2 will be raised to the same amount, and the circumference of the pulley A will move through the same space. Supposing that the line 3 were fixed at its extremity, the pulley B would be raised by half the amount to which the line 2 is shortened. But the revolution of the pulley A, whilst it draws up the line 2 over one groove, lets down the line 3 from the other. If the two grooves were of the same size, therefore, the pulley B would not be raised, since the line 3 would descend as much as 2 ascends. But, in consequence of the different size of the grooves, the line 3 does not descend as fast as 2 ascends; and the rise of the pulley B will, therefore, be equal to half the difference in the amount. But if the larger groove have a circumference of 18 inches, and the smaller of 15 inches, the line 2 will be drawn up by one revolution of the pulley A through 18 inches, whilst the line 3 will descend through 15. The movable pulley B, with the weight attached to it, will consequently be made to ascend through $1\frac{1}{2}$ inches, whilst P descends 18, and the power gained will be 12.

"The reason of this gain of power is at once seen, by considering that the action of the weight upon the string 3 tends to turn round the pulley in the direction of the arrow nearly as much as the action of the string 2 tends to turn it in a contrary direction; and that a small force applied to P will, therefore, overcome the difference. If, as in the present instance, the distance from C to D be 15, and from C to E 18, a weight bearing on the string 3 would cause the pulley A to move in the direction of the arrow with a power of 15, whilst the same pressure on the line 2 would make it turn in the contrary direction with a power of 18. The difference between the two strains, therefore, will be the real amount of resistance to be overcome by a power applied to the circumference of the larger groove of the pulley A; and this will be one-sixth of the strain upon either of the strings. But

this strain is only half the total weight suspended to B, and the power of the combination will hence be 12. It may be increased to any amount, by diminishing the difference between the two grooves. Thus, if the larger one have a diameter of 100 parts, and the smaller one of 99, the resistance to the motion of the upper pulley will only be 100th part of the weight bearing on each string, or 200th of the whole weight suspended to B. As the cord has no fixed extremity, and as the action of the pulleys would be altogether destroyed if it had the power of *sliding* over them, it is necessary to take some means of preventing this. The simplest is the employment of a chain, instead of a cord, the links of which are laid hold of by pins projecting from the surface of the wheels. The author may express his surprise that this ingenious invention has not come into more general use, since it enables any amount of power to be obtained without any corresponding enlargement of the apparatus, or increase of friction."

I now find that Mr. Weston has patented this invention of twenty years since—another instance of wasted money from imperfect investigation.

I am, sir, yours, obediently, ARTIZAN.

London, Sept. 15, 1862.

---

For the Journal of the Franklin Institute.

## *Air as a Motive Power in Cities.*

Two or three years ago, French papers announced that application had been made to the authorities of the City of Paris for permission to establish a system of pipes, similar to those used in the distribution of gas or water, for the introduction and circulation of compressed air, to be used as a motive power where required throughout the city; that the air thus furnished, from pneumatic reservoirs without the walls, would be under the entire control of the operative, being turned on or off at will like gas, a meter indicating the quantity used by each person; that it would not only move machinery, but may be economically applied to ventilation, warming dwellings, and elevating water, while a simple turncock might replace the cumbrous bellows used in forges and blast furnaces; that this use of air would be entirely void of danger, and that should a pipe burst, the escaping fluid could be injurious to the company only by its loss.

What became of the project I know not. A practicable one obviously, and that in some locations it would be a valuable one, is equally manifest; as where the tides, or falling water, can be made to compress the fluid at little or no cost. I think, however, that a safer, cheaper, and much better plan would be to keep the tubes empty of air: that is, to use the atmospheric pressure as the force, and the vacuum in the tubes to excite it. That this can be profitably done in many towns and cities I have no doubt, nor yet that it will be done. Though the force is more limited than compressed air, it has more than compensating advantages.

The adaptation of atmospheric pressure to movable mechanisms—

to railroad and common road carriages, to ploughing, reaping, and other agricultural operations, &c., is quite another question. As respects it, the engineer is still waiting for the chemist. We have no cheap and ready means of expelling air from under a piston, nor any such for getting rid of it by decomposition. If it could be instantly and economically reduced to a few drops of liquid (like the constituent gases of water), the object would be attained. Its partial expulsion by heat, as in the cupping-glass, or when rendered explosive, requires time for it and the cylinder to cool. It is the same when low steam and the vapor of alcoholic dilutions are used. In these cases cheap freezing-mixtures would go far to remove the difficulty, but they are not to be had. In fact, all the contrivances for producing a vacuum, yet devised, are too costly and tedious to serve the purpose. But that chemistry has something in store for us that will enable us to convert the pressure of the atmosphere into a popular motor, need not I think be questioned. E.

---

*On the Change of Form assumed by Wrought Iron and other Metals when Heated and then Cooled by Partial Immersion in water.* By Lieut. Col. H. CLERK, R. A., F. R. S.

From the Lond. Proceedings of the Royal Society, March, 1863.

(Continued from page 190.)

*Experiment* 10.—A hollow brass cylinder, 6 inches long, 2 inches in diameter, and $\frac{1}{16}$th of an inch thick, was heated to redness and cooled by half immersion thirty-four times.

Fig. 16.

One-half of full size. The dotted lines indicate the original figure.

The effect produced was the opposite to that which took place with the iron cylinders, being an expansion instead of a contraction at the water-line, the amount of which was ·175 inch, and it was also expanded on the lower edge ·1 inch (see fig. 16).

*Experiment* 11.—A hollow gun-metal cylinder was heated to redness and cooled twenty times by half immersion.

The thickness of metal being greater than in the last experiment, the effect at the water-line was much less, but the lower edge had expanded ·1 inch. It began to crack all over at the last cooling.

*Experiment* 12.—A hollow tin cylinder was heated in linseed oil which was brought to a temperature of 400° Fahr.; it was cooled by half immersion in water five times.

The form was not altered in the least, though the heat was raised in the last instance to the melting point, as shown by the lower part of the cylinder beginning to melt.

*Experiment* 13.—A hollow zinc cylinder was heated and cooled by half immersion fifty times.

It was heated in a wood furnace, the degree of heat to which it was brought being regulated by the melting of a piece of tin which was conveyed at the same time with it into the furnace. Several experiments with pieces of tin and zinc had been previously made, by means of which it was ascertained that in the same temperature tin melted in two-sevenths of the time requisite to melt zinc; hence when the zinc cylinder and piece of tin were placed in the furnace together, the time occupied by the tin in reaching its melting-point was carefully noted, and the cylinder was left in the furnace as long again as the time thus observed; by this means it was brought very nearly to its melting-point without incurring any danger of its actually melting. The last five times, however, it was allowed to remain a little longer in the flame; and the melting upon the top was retarded the last four times by placing a piece of iron upon it, which conducted heat from that part, allowing it to remain half a minute longer in the furnace.

Fig. 17.

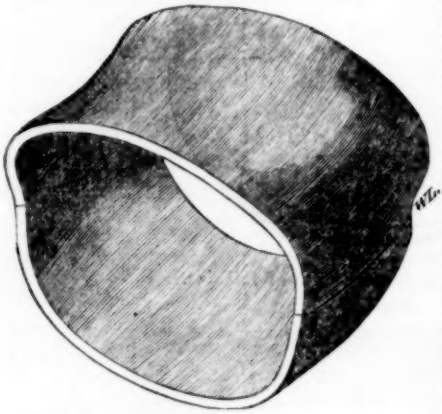
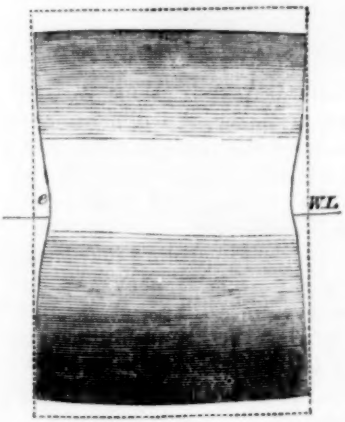



Fig. 18. [Side view of fig. 17.]




The effect obtained was the same as that produced upon the brass cylinder (Exp. 10), or the opposite of what took place with iron; an expansion of ·175 inch occurred upon the water-line, and of ·115 inch upon the lower edge.

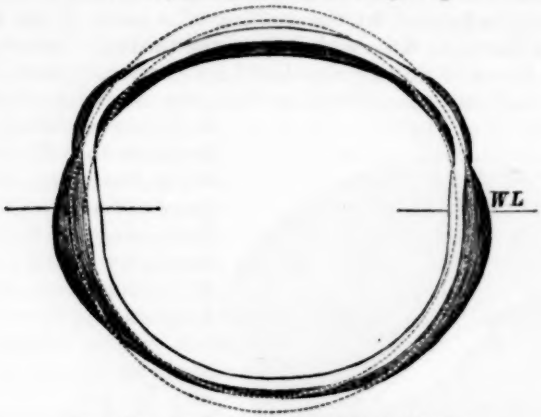
*Experiment* 14.—The hollow wrought iron cylinder was heated to redness and cooled by half immersion on its *side*, instead of on its end as in other experiments, twenty times.

The effect was a very complicated one (see figs. 17, 18, and 19); the dotted lines show the original form.

*Experiment* 15.—A solid wrought iron cylinder was heated to redness and cooled by half-immersion on its side twenty times.

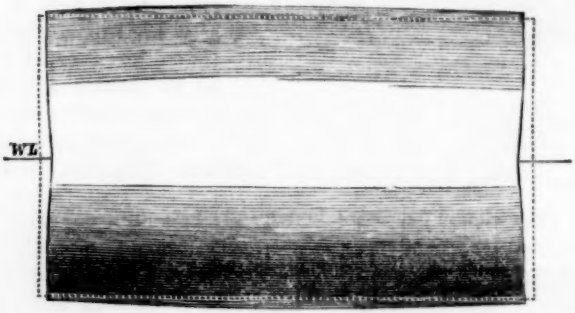
The effect was of a similar nature to that of the last experiment (see figs. 20 and 21).

Fig. 19. [Front view of fig. 17.]




The three figures are one-sixth of full size.

Fig. 20.




One-half of full size. The dotted line indicates original figure.

*Experiment* 16.—A hollow cast iron cylinder, the dimensions of which were the same as those of the deep cylinder experiment 14, was heated to redness and cooled twice by half-immersion.

Fig. 21.

One-half of full size. The dotted line indicates original figure.

At the second cooling it fractured nearly all around, about an inch below the water-line. It expanded all over, but the expansion was least about an inch above the water-line, *i.e.* it did not contract to its original dimensions.

*Experiment* 17.—A solid cast iron cylinder, 3 inches in diameter and 6 inches deep, was heated and cooled five times by half-immersion.

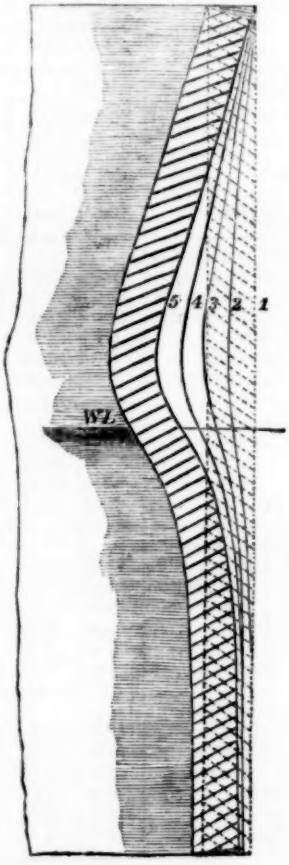
At the fifth cooling it cracked

across the bottom; it also expanded throughout, and the expansion was least a little above the water-line, *i. e.* it did not contract to its original dimensions.

The subjoined figures (half the full size) show the changes produced on the 9-inch cylinders after every five heatings. (Experiments 2 and 4.)

Fig. 22.

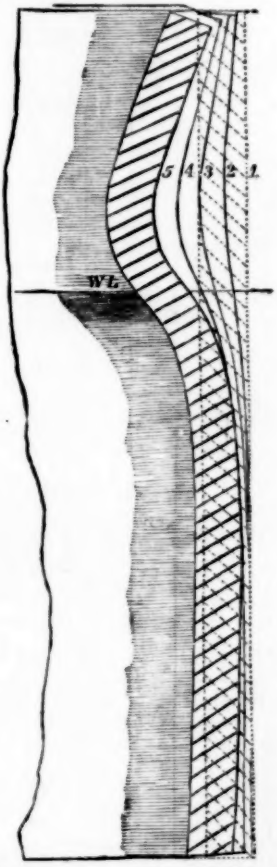
12″ Cylinder, 9″ high, ½″ thick.
*Vide* fig. 4. Cooled by ½-immersion.




No. 1. External surface, original form.
2. " " after 5 coolings.
3. " " " 10 "
4. " " " 15 "
5. " " " 20 "

Fig. 23.

12″ Cylinder, 9″ high, ½″ thick.
*Vide* fig. 7. Cooled by ⅔-immersion.




No. 1. External surface, original form.
2. " " after 5 coolings.
3. " " " 10 "
4. " " " 15 "
5. " " " 20 "

TABULATED STATEMENT OF THE RESULTS OF THE EXPERIMENTS.

| Number of Experiment. | Kind of metal. | Number of coolings. | Amount of immersion. | Form of article, &c. | Dimensions in inches. Before experiment. | After experiment. | Difference. |
|---|---|---|---|---|---|---|---|
| 1[a]. | Wrought iron. | 5 | ½ | Hoop-tire for a 4′ 2″ wheel :— | | | |
| | | | | External circumf. of upper edge | 155·5 | 147·5 | —8·0 |
| | | | | " " lower " | 155·5 | 156·375 | +0·875 |
| | | | | Bevel of face, . . | 90° | 69° | —21° |
| 2b. | Wrought iron. | 20 | ½ | 12″ cylinder, 9″ deep & ½″ thick: | | | |
| | | | | Internal circumf. of upper edge | 37·6 | 37·6 | . . |
| | | | | " " contraction | 37·6 | 32·1 | —5·5 |
| | | | | " " lower edge | 37·6 | 37·0 | —0·6 |
| | | | | Depth, perpendicular . | 9·0 | 8·8 | —0·2 |
| | | | | " on curve, external . | 9·0 | 9·15 | +0·15 |
| | | | | " " internal . | 9·0 | 9·35 | +0·35 |
| 2c. | Wrought iron. | 20 | ½ | 12″ cylinder, 6″ deep & ½″ thick: | | | |
| | | | | Internal circumf. of upper edge | 37·6 | 36·9 | —0·70 |
| | | | | " " contraction | 37·6 | 32·35 | —5·25 |
| | | | | " " lower edge | 37·6 | 37·9 | +0·30 |
| | | | | Depth, perpendicular . | 6·0 | 5·7 | —0·30 |
| | | | | " on curve, external . | 6·0 | 6·05 | +0·05 |
| | | | | " " internal . | 6·0 | 6·30 | +0·30 |
| 3d. | Wrought iron. | 10 | ½ | 12″ cylinder, 9″ deep, thin sheet: | | | |
| | | | | External circumf. of upper edge | 38·40 | 38·40 | . . |
| | | | | " " contraction | 38·40 | 34·90 | —3·50 |
| | | | | " " lower edge | 38·40 | 38·45 | +0·05 |
| | | | | Depth, on curve . . | 9·00 | 9·15 | +0·15 |
| 4e. | Wrought iron. | 20 | ⅜ | 12″ cylinder, 9″ deep & ½″ thick: | | | |
| | | | | External circumf. of upper edge | 40·90 | 38·80 | —2·10 |
| | | | | " " contraction | 40·90 | 35·00 | —5·90 |
| | | | | " " lower edge | 40·90 | 40·00 | —0·90 |
| | | | | Depth, perpendicular . | 9·00 | 8·80 | —0·20 |
| | | | | " on curve, external . | 9·00 | 9·00 | . . |
| | | | | " " internal . | 9·00 | 9·35 | +0·35 |
| 4f. | Wrought iron. | 20 | ⅜ | 12″ cylinder, 6″ deep & ½″ thick: | | | |
| | | | | External circumf. of upper edge | 40·8 | 37·2 | —3·6 |
| | | | | " " contraction | 40·8 | 36·2 | —4·6 |
| | | | | " " lower edge | 40·8 | 40·15 | —0·65 |
| | | | | Depth, perpendicular . | 6·0 | 6·0 | . . |
| | | | | " on curve, external . | 6·0 | 6·05 | +0·05 |
| | | | | " " internal . | 6·0 | 6·15 | +0·15 |
| 5g. | Wrought iron. | 15 | ½ | 3″ cylinder, 6″ deep, solid : | | | |
| | | | | Circumference, upper edge . | 9·4 | 9·3 | —0·1 |
| | | | | " contraction . | 9·4 | 8·95 | —0·45 |
| | | | | " lower edge . | 9·4 | 8·95 | —0·45 |
| | | | | Bulge on upper end . | . . | 0·04 | +0·04 |
| | | | | " lower end . | . . | 0·15 | +0·15 |

[a] For remarks see end of Table, p. 260.

TABLE (Continued.)

| Number of experiment. | Kind of metal. | Number of coolings. | Amount of immersion. | Form of article, &c. | Dimensions in inches. Before experiment. | After experiment. | Difference. |
|---|---|---|---|---|---|---|---|
| 6h. | Wrought iron. | 15 | ⅔ | 3″ cylinder, 6″ deep, solid:— | | | |
| | | | | Circumference, upper end . | 9·40 | 9·35 | −0·05 |
| | | | | " contraction . | 9·40 | 9·00 | −0·40 |
| | | | | " lower edge . | 9·40 | 9·05 | −0·35 |
| | | | | Bulge on upper end . | . . | 0·05 | +0·05 |
| | | | | " lower end . . | . . | 0·20 | +0·20 |
| 7i. | Wrought iron. | 20 | ½ | Flat piece, 12″ × 6″ × ½″:— | | | |
| | | | | Length on curve, upper edge . | 12·00 | 10·75 | −1·25 |
| | | | | " " lower edge . | 12·00 | 12·10 | +0·10 |
| | | | | Breadth, ends . . | 6·00 | 5·75 | −0·25 |
| | | | | " centre . . | 6·00 | 6·00 | . . |
| | | | | Upper edge, out of straight . | . . | 0·60 | +0·60 |
| | | | | Indentation on ends . | . . | 0·30 | +0·30 |
| 7k. | Wrought iron. | 20 | ⅔ | Flat piece, 12″ × 6″ × ½″:— | | | |
| | | | | Length on curve, upper edge . | 12·00 | 11·10 | −0·90 |
| | | | | " " lower edge . | 12·00 | 12·20 | +0·20 |
| | | | | Breadth. ends . . | 6·00 | 5·87 | −0·13 |
| | | | | " centre . . | 6·00 | 5·95 | −0·05 |
| | | | | Upper edge, out of straight . | . . | 0·50 | +0·50 |
| | | | | Indentation on ends . | . . | 0·15 | +0·15 |
| 8l. | Wrought iron. | 15<br>10 | . .<br>total | 12″ cylinder, 9″ deep, ½″ thick<br>" " " | No effect. | | |
| 9m. | Cast steel. | 20 | ½ | 3″ cylinder, 6″ deep, solid:— | | | |
| | | | | Circumference, upper edge . | 9·03 | 8·93 | −0·10 |
| | | | | " contraction . | 9·03 | 8·65 | −0·38 |
| | | | | " lower edge . | 9·03 | 8·93 | −0·10 |
| | | | | Depth, perpendicular . | 6·00 | 6·10 | +0·10 |
| 10n | Brass. | 34 | ½ | 2″ cylinder, 6″ deep, 1-16″ thick: | | | |
| | | | | External circumf. of upper edge | 6·175 | 6·175 | . . |
| | | | | " " expansion | 6·175 | 6·350 | +0·175 |
| | | | | " " lower edge | 6·175 | 6·270 | +0·095 |
| 11o. | Gun-metal. | 20 | ½ | 3″ cylinder, 6″ deep, ½″ thick:— | | | |
| | | | | External circumf. of upper edge | 9·25 | 9·24 | −0·01 |
| | | | | " " on water-line | 9·25 | 9·26 | +0·01 |
| | | | | " " of lower edge | 9·25 | 9·38 | +0·13 |
| 12. | Tin. | 5 | ½ | 2″ cylinder, 5″ deep, ¼″ thick:— | No effect. | | |
| 13. | Zinc. | 50 | ½ | 3″ cylinder, 6″ deep, ½″ thick:— | | | |
| | | | | External circumf. of upper edge | 9·525 | 9·575 | +0·050 |
| | | | | " " expansion | 9·525 | 9·700 | +0·175 |
| | | | | " " lower edge | 9·525 | 9·630 | +0·105 |

TABLE (Continued.)

| Number of experiment. | Kind of metal. | Number of coolings. | Amount of immersion. | Form of article, &c. | Dimensions in inches. Before experiment. | After experiment. | Difference. |
|---|---|---|---|---|---|---|---|
| 14p. | Wrought iron. | 20 | ½ on its side. | 12″ cylinder, 9″ deep, ½″ thick:— | | | |
| | | | | External circumference of edges | 40·65 | 39·86 | —0·79 |
| | | | | " " centre | 40·65 | 41·05 | +0·40 |
| | | | | Depth on curve, part cooled in air. | 9·00 | 9·00 | . . |
| | | | | " " water-line. | 9·00 | 8·25 | —0·75 |
| | | | | " " in water | 9·00 | 8·80 | —0·20 |
| | | | | Swell of side, 1″ below W.L. (at *a*, *b*) | . . | 1·00 | +1·00 |
| | | | | Hollow of side, 4″ above do. (at *c*, *d*) | . . | 0·40 | +0·40 |
| | | | | Longest ex. diam. 1″ below W.L. | 12·94 | 14·275 | +1·335 |
| | | | | Shortest do. at rt. angles to W.L. | 12·94 | 12·00 | —0·94 |
| | | | | Indentation of edges a little above water-line at *e* | . . | 0·45 | +0·45 |
| 15q. | Wrought iron. | 20 | ½ on its side. | 3″ cylinder, 5¾″ deep, solid:— | | | |
| | | | | External circumference of edges | 9·4 | 9·2 | —0·2 |
| | | | | " " centre | 9·4 | 9·475 | +0·075 |
| | | | | Depth along part cooled in air | 5·375 | 5·150 | —0·225 |
| | | | | " " on W.L. | 5·375 | 5·100 | —0·275 |
| | | | | " " in water | 5·375 | 5·225 | —0·150 |
| | | | | Longest diam. at rt. angles to W.L. | 3·000 | 3·100 | +0·100 |
| | | | | Shortest " parallel with W.L. and a little below it | 3·000 | 2·760 | —0·240 |
| 16. | Cast iron. | 2 | ½ | 12″ cylinder, 9″ deep, ½″ thick:— | | | |
| | | | | External circumf. of upper edge | 40·90 | 41·05 | +0·15 |
| | | | | " " least expansion | 40·90 | 40·95 | +0·05 |
| | | | | " " of lower edge— | 40·90 | 41·15 | +0·25 |
| 17. | Cast iron. | 5 | ¼ | 3″ solid cylinder, 6″ deep:— | | | |
| | | | | External circumf. of upper edge | 9·4 | 9·55 | +0·15 |
| | | | | " " least expansion | 9·4 | 9·50 | +0·10 |
| | | | | " " of lower edge | 9·4 | 9·55 | +0·15 |

REMARKS.

[a] The width was unaltered, and the thickness of the upper edge slightly increased. Figs. 1 and 2. [b] Fig. 4. [c] Fig. 5. [d] Fig. 6. [e] Fig. 7. [f] Fig. 8.

[g] The fibre opened at the fifteenth cooling. Fig. 9.

[h] The fibre opened at the fifteenth cooling after having exhibited a slight crack for two or three previous coolings. Fig. 10.

[i] The thickness of the metal at the indentation on ends increased ·1″. Fig. 11.

[k] The thickness of the metal at the indentation on ends increased similarly to the last. Fig. 12.

[l] Cooled in air 15 times. Cooled in water 10 times.

[m] The ends became slightly rounded. Fig. 13.

[n] At the last cooling the lower end of the cylinder began to crumble away in the water. Fig. 16.

[o] The expansion of the lower end may probably be due to the cracking of the metal, which was greatest at that part.

[p] Figs. 17, 18, 19. There was an increased thickness of metal at *e*.

[q] Figs. 20, 21.

[The cause of the curious phenomenon described by Colonel Clerk in the preceding paper seems to be indicated by some of the figures, especially those relating to hollow cylinders of wrought iron, which are very instructive.

Imagine such a cylinder divided into two parts by a horizontal plane at the water-line, and in this state immersed after heating. The under part, being in contact with water, would rapidly cool and contract, while the upper part would cool but slowly. Consequently by the time the under part had pretty well cooled, the upper part would be left jutting out; but when both parts had cooled, their diameters would again agree. Now in the actual experiment this independent motion of the two parts is impossible, on account of the continuity of the metal; the under part tends to pull in the upper, and the upper to pull out the under. In this contest the cooler metal, being the stronger, prevails, and so the upper part gets pulled in, a little above the water-line, while still hot. But it has still to contract on cooling; and this it will do to the full extent due to its temperature, except in so far as it may be prevented by its connexion with the rest. Hence, on the whole, the effect of this cause is to leave a permanent contraction a little above the water-line; and it is easy to see that the contraction must be so much nearer to the water-line as the thickness of the metal is less, the other dimensions of the hollow cylinder and the nature of the metal being given. When the hollow cylinder is very short, so as to be reduced to a mere hoop, the same cause operates; but there is not room for more than a general inclination of the surface, leaving the hoop beveled.

But there is another cause of deformation at work, the operation of which is well seen in figs. 2 and 3. Imagine a mass of metal heated so as to be slightly plastic, and then rapidly cooled over a large part of its surface. In cooling, the skin at the same time contracts and becomes stronger, and thereby tends to squeeze out its contents. This accounts for the bulging of the ends of the solid cylinders of wrought iron and the rents seen in their cylindrical surface. The skin at the bottom is of course as strong as at the sides in the part below the water-line; but a surface which resists extension far more than bending has far less power to resist pressure of the nature of a fluid pressure when plane than when convex. The effect of the cause first explained is also manifest in these cylinders, although it is less marked than in the case of the hollow cylinders, as might have been expected.

The tendency of the cooled skin of a heated metallic mass to squeeze out its contents appears to be what gives rise to the bulging seen near the water-line in the hollow cylinder of brass. Wrought iron, being highly tenacious even at a comparatively high temperature, resists with great force the sliding motion of the particles which must take place in order that the tendency of the cooled skin to squeeze out its contents may take effect; but brass, approaching in its hotter parts more nearly to the state of a molten mass, exhibits the effect more strongly. It seems probable that even in the case of brass a *very* thin hollow cylinder would exhibit a contraction just above the water-line.

Should there be a metal or alloy which, about the temperatures with which we have to deal, was stronger hot than cold, the effect of the cause first referred to would be to produce an expansion a little below the water-line. G. G. S.]

---

Translated for the Journal of the Franklin Institute.

### *Presence of Phosphorus in Cast Iron.*

The following note was presented to the French Academy of Sciences by Captain Caron:—

The numerous attempts which I have made to eliminate the phosphorus from cast iron have been heretofore unsuccessful, and I have never been able to establish that cast iron absorbs a great part of whatever phosphorus it may find around it at the moment of its formation, especially if the slags be siliceous. Thus, having several times treated ores entirely free from phosphorus, with charcoal to which phosphate of lime and silica had been added, I have always found in the cast iron almost the whole of the phosphorus which I had put in the crucible as a phosphate. Thus the exact results of some of my experiments were as follows: a carbonate of iron from Benndorff was reduced in a crucible lined with charcoal mixed with phosphate of lime. The quantity of phosphate was so calculated as to be able to introduce 1 per cent. of phosphorus into the cast iron.

| | | Phosphorus in the Cast Iron. |
|---|---|---|
| No. 1. | Reduction with 15 per cent. of silica, . | 0·92 per cent. |
| 2. | " 10 " " . | ·89 " |
| 3. | " 5 " " . | ·87 " |
| 4. | " without addition, . . | ·85 " |
| 5. | " with 5 per ct. of carbonate of lime, | ·82 " |
| 6. | " 10 " " " | ·82 " |

Since no way exists of removing phosphorus from cast iron, and they never fail to combine when they meet, it will be very important to remove all causes which may contribute to introduce this hurtful metalloid. Among these causes is one to which usually but little importance is attached, but which nevertheless appeared to me to deserve examination—that is, the chemical composition of the cinders of the fuel.

Almost every wood contains phosphorus, so that castings made with charcoal, although the ore may not have contained any, will still contain at least 0·2 per cent. In this proportion phosphorus is not hurtful, but when it rises to a proportion of 0·7 per cent. its injurious properties become manifest; it is therefore important to use such fuel as cannot give phosphorus in this latter proportion to the castings. Now different woods differ in their proportions of phosphorus, not only according to the nature of the soil in which they grow, but also according to their different species. Berthier (*Essais sur la voie séche*, t. I. p. 262) has made on this subject analyses which are known to all metallurgists. For instance, oak from *la Roque-les Arts*, whose ashes contain but 0·008 of phosphoric acid, could not be replaced by the

hornbeam of the Somme and the Nieve, whose ashes contain 0·09 or 0·1 of that compound. As these two woods give about the same amount of ashes, it is evident that the oak which could only introduce 0·12 per cent. of phosphorus into the iron, would be preferable to the hornbeam, which might introduce at least 1 per cent.—*Cosmos.*

---

For the Journal of the Franklin Institute.

## *On a New System of Arithmetic and Metrology, called the Tonal System.*

By John W. Nystrom, C. E.

Counting has in all ages been a troublesome operation to mankind; the first mode of counting was performed on the fingers, and limited first to five; then to ten, including the fingers on the two hands; and then to twenty, including the toes on the feet, which is yet the extent of counting with some tribes on our globe. The more intelligent tribes arranged their mode of counting into systems with five, ten, and some twenty as the base, and named their numbers and bases from the fingers, hands, and feet, which is probably more ancient than even languages. We can easily trace from many oriental languages that the term *five* means hand, *ten* two hands, and *twenty* a man, which includes fingers and toes.

The Kamtschatkans have to a very late period continued the counting on the fingers, and even yet, in the interior of the peninsula, the inhabitants count on their fingers to ten, when they clasp their hands together, then continue on their toes to twenty, when they become confused, and cry out "matuchka, matuchka," which means "mother, mother," a very common expression of excitement in the north-eastern languages.

The Hindoos seem to have been the first to adopt and introduce a uniform and complete system of calculation, with ten for the base, evidently derived from the ten fingers on the hands, which constitutes our present system of arithmetic, introduced into Europe about 900 years ago, but was probably known by the Hindoos in the time of Christ. The Roman notation was used in Europe before the introduction of the Hindoo arithmetic, and was continued in England as late as to about thirty years ago. The Hindoo arithmetic was at first unfavorably received, and in many cases met with great resistance, owing to the clumsy Roman notation which was then as firmly established in their minds as our present arithmetic is with us.

The base ten in our present system of counting was thus originated from the ten fingers on the hands by perhaps the first tribes of the human race, who had no knowledge whatever of mathematics, and in consequence were wholly incapable of selecting a proper number for such an important position. Ten has no claim whatever as a base for counting; it is in reality the most unsuitable number that could reasonably be selected, of which complaints have constantly been made, and better numbers proposed.

Charles XII. of Sweden gave the numbers 8, 12, and 16, a careful

consideration about 150 years ago. He first selected 12, which had many advantages over 10, being divisible by 2, 3, 4, and 6, but had only one more binary division than 10. He then selected 16, which is a square of 4, and the fourth power of 2; this he thought was the best number for the base of arithmetic, but objected to the addition of new characters. The number 8 was then selected, and worked out to a complete system of arithmetic and metrology, with the intention of introducing it in Sweden. Charles XII. said, "It is quite ridiculous to use *ten* as the base for arithmetic; it can be divided only once by 2, and then stops."

Mr. Alfred B. Taylor, of Philadelphia, proposes the number 8 as an arithmetical base, and has given a very complete and interesting historical and critical account of the decimal system, and advantages of an octonal base, published in the "Transactions of the American Pharmaceutical Association" for 1859.

The writer proposes the number 16 as a base, and has worked out a complete system of arithmetic and metrology, called the *Tonal system*, which was submitted to the International Decimal Association, and read at their meeting held at Bradford, Yorkshire, October 11th, 1859. A complete description of the *Tonal system* is published by J. B. Lippincott & Co., Philadelphia.

Our objection to the decimal arithmetic is, that the base 10 does not admit binary divisions without fractions, which is a great inconvenience, and burdens the mind in counting. In practice we desire to divide things into the most natural fractions, as halves, quarters, eighths, sixteenths, &c., which in our present arithmetic give long decimal tails, as 0·25, 0·125, 0·0625, very unnatural and ungain expressions to use in the shop and the market. If 0·125 be shown to the people, very few without special education would understand its true meaning; and if they be told that 0·125 means one-eighth, it will be necessary to explain that the whole is divided into 1000 parts, and that 125 parts is one-eighth of the whole. The people will then naturally reply that this is a roundabout way, and that they are not willing to divide their articles into 1000 parts in order to obtain an eighth. Among the best arithmeticians, there are very few who clearly comprehend that 125 is one-eighth of 1000, but it is well known to be so by practice in counting.

In the *Tonal system*, with 16 as the base, it is easily comprehended that 0·4 is $\frac{1}{4}$, as 4 is $\frac{1}{4}$ of 16, and that 0·2 is $\frac{1}{8}$, because 2 into 16 goes 8 times; for the natural fractions the mind is not carried further than to the base 16.

Attempts are now being made in most parts of the civilized world, and an association has been formed for many years, for the purpose of introducing an international decimal system of metrology, but they constantly meet with the most natural and reasonable objections. Mr. Taylor says, "Decimal numeration is natural only in the sense that *ignorance* is natural." We know that the base 10 originated with the first people on earth, in the very rudest state of ignorance, when they even had no use for a system of metrology; but when they became

more enlightened, accustomed to counting, and adopted systems of metrology, they found that it was easier to manage series of aliquot numbers, and therefore divided their units into parts of 8, 12, 16, 24, 32, &c. Further, when we became more accomplished in the science of arithmetic, those who had to do with numbers merely by pen and ink discovered that units could also be divided into the absurd number 10 or 100 parts, and so the complication is dragged along and propagated by a few decimal professors, who have little or nothing to do with the practical application of numbers in the shop or the market. Unfortunately, these professors generally occupy influential positions, and are perfect barricades against improvements in counting, which have been repeatedly suggested by practical men. The arguments of the decimal defenders are generally of a most feeble character; they confine themselves to mere triflings and some temporary importance, which have no bearing whatever on the utility of proposed improvements in arithmetics. See Nystrom's *Tonal System*, published by Lippincott & Co., Philadelphia, in which the subject is discussed from both sides. The writer has taken great pleasure in publishing remarks from the decimal side, with the view of giving the subject a fair ventilation.

The decimal system is very convenient in the mechanical operation of calculation, when it is not necessary to impress the values on the mind, as is the case with many arithmeticians, who manage the figures and come to the result as easily as a musician who plays the hand-organ; but it is not so easy for practical men and self-thinkers, who impress the values and relative positions of quantities on their mind, as they proceed in measurement and calculation. The new system about to be described has all the advantages and covers all the disadvantages of the decimal system. The reader will now be led into a new system of arithmetic, with the number 16 as the base, called the *Tonal System*. It is hoped he will give the subject a careful consideration, and not allow himself to be discouraged by the new names and figures, which naturally will appear strange at the first glance; reflection will soon lead to a conviction of its simplicity and importance.

---

Tonal System.—In the *Tonal System* it is proposed to add six new figures to the ten arabic, thus:

1, 2, 3, 4, 5, 6, 7, 8, 9, ↊, ↋, ↌, ↍, ↎, 10,

making 16 characters to form the base. In order to form a clear conception of the nature and utility of the *Tonal System*, it will be well to enter into some details of calculation with examples, in connexion with which it is necessary to give names to the new figures, or rather to give new names to the 16 characters, so as to clearly distinguish it from our present system.

A new system of this kind could not well be introduced in one country alone, but the whole world at large must agree on its acceptance; it then becomes necessary in the project of the system, to select such names of the figures as to make it well suited to all languages, both

in spelling and sound; for which the following names are given, without reference to any language or thing. It is desirable to have the names clear and simple, in expressing as well compound numbers as the different units for measures. It is not necessary to employ more than one syllable for each object expressed.

*Tonal Names of Single Figures and Compound Numbers.*

| | | | | | |
|---|---|---|---|---|---|
| 0. | Noll. | 17. | Tonra. | 4ℓ. | Titonfy. |
| 1. | An. | 18. | Tonme. | 40. | Goton. |
| 2. | De. | 19. | Tonni. | 43. | Gotonti. |
| 3. | Ti. | 19. | Tonko. | 46. | Gotonby. |
| 4. | Go. | 1ℓ. | Tonhu. | 4ℓ. | Gotonhu. |
| 5. | Su. | 1℣. | Tonvy. | 50. | Suton. |
| 6. | By. | 1ℰ. | Tonla. | 80. | Meton. |
| 7. | Ra. | 1ℨ. | Tonpo. | ℓ0. | Huton. |
| 8. | Me. | 1ℓ. | Tonfy. | ℓ8. | Vytonme. |
| 9. | Ni. | 20. | Deton. | ℨℓ. | Potonfy. |
| ℓ. | Hu. | 21. | Detonan. | ℓ5. | Fytonni. |
| ℣. | Vy. | 22. | Detonde. | 100. | San. |
| ℰ. | La. | 24. | Detongo. | 101. | Sanan. |
| ℨ. | Po. | 26. | Detonby. | 102. | Sande. |
| ℓ. | Fy. | 28. | Detonme. | 106. | Sanby. |
| 10. | Ton. | 2ℓ. | Detonhu. | 10ℨ. | Sanpo. |
| 11. | Tonan. | 2℣. | Detonpo. | 110. | Santon. |
| 12. | Tonde. | 30. | Titon. | 11ℓ. | Santonhu. |
| 13. | Tonti. | 31. | Titonan. | 120. | Sandeton. |
| 14. | Tongo. | 32. | Tidonde. | 129. | Sandetonko. |
| 15. | Tonsu. | 35. | Titonsu. | 130. | Santiton. |
| 16. | Tonby. | 39. | Titonko. | 145. | Sangotonsu. |
| | | 3℣. | Titonvy. | 200. | Desan. |

| | |
|---|---|
| 28ℓ. | Desan-metonfy. |
| 700. | Rasan. |
| ℓ℣ℓ. | Husan-vytonfy. |
| 1000. | Mill. |
| 2000. | Demill. |
| 8ℓ℣5. | Memill-husan-vytonsu. |
| 1,0000. | Bong. |
| ℓ,0610. | Vybong,bysanton. |
| 10,0000. | Tonbong. |
| 100,0000. | Sanbong. |
| 1,0000,0000. | Tam. |

The names of the *Tonal Figures* are contained in the following four words, *Andetigo*, *Subyrame*, *Nikohuvy*, *Lapofyton*, which should be learned by heart. The vowel *y* in these names should be pronounced as in the English word *cylinder*, *i* as in *will*, *e* as in *then*, *a* as in *father*.

This arrangement of expressing numbers is clear and simple, but it requires some practice before the sound impresses the corresponding

value on the mind, for which it is necessary to have a clear conception of the sound and value of each figure.

The number 145 is expressed in the *Tonal, Sangotonsu.*

The new names in the tonal system may first appear objectionable, but some reflection will soon lead to the conviction, that there is no other language so simple in expressing the same thing. Could we only attain the consent of nations to change the base of arithmetic, we would have no difficulty about the new names, for each nation could select their own tonal language; but when new names must be adopted, we may as well agree on one denomination. The Greek and Latin languages have been avoided for the very reason of their complication, neither would it be proper to adopt those names derived from the fingers, hands, toes, and feet, with which the tonal system has no connexion whatever. The Greek and Latin names may be very clear to the few who are familiar with those languages, but we have now experienced in the French system, how unsuitable they are in practice.

*Decimal*, one hundred and forty-five.

The Tonal system requires only 10 letters, where the decimal system employs 22.

The object of employing different consonants to the names of the figures is to render it more difficult to alter a written number from one value to another; it will also make the expression clearer. Although the old figures in the *Tonal System* bears the old value (except 9) one by one, it will not be so in compound numbers, as will be seen in the following table I:

*Explanation of Tables.*

TABLE I shows the different notations of equal numbers in the *decimal* and *tonal* systems, where it will be seen that the new system requires a less number of figures in expressing a high number; *decimal* 134 = 86 *tonal*, yet the real value is the same in both cases.

TABLE II is a further extension of Table I, useful for transferring numbers from one system to the other.

EXAMPLE 1. Required how the number 31,868 will be noted by the *tonal system?*

| | | | |
|---|---|---|---|
| *Decimal.* | 30,000 = | 7550 | *Tonal.* |
| | 1,000 = | 388 | |
| | 800 = | 320 | |
| | 68 = | 44 | |
| | 31,868 = | 7850 | |

EXAMPLE 2. The year 1863 expressed by the *tonal system* will be 748, or it would apparently carry us back over 11 centuries.

EXAMPLE 3. A lady of 35 years will be noted 23 in the *tonal system.*

TABLE I.

*Notation of Tonal and Decimal Numbers.*

| Decimal. | Tonal. | Decimal. | Tonal. | Decimal. | Tonal. | Decimal. | Tonal. |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 33 | 21 | 65 | 41 | 97 | 61 |
| 2 | 2 | 34 | 22 | 66 | 42 | 98 | 62 |
| 3 | 3 | 35 | 23 | 67 | 43 | 99 | 63 |
| 4 | 4 | 36 | 24 | 68 | 44 | 100 | 64 |
| 5 | 5 | 37 | 25 | 69 | 45 | 101 | 65 |
| 6 | 6 | 38 | 26 | 70 | 46 | 102 | 66 |
| 7 | 7 | 39 | 27 | 71 | 47 | 103 | 67 |
| 8 | 8 | 40 | 28 | 72 | 48 | 104 | 68 |
| 9 | 9 | 41 | 29 | 73 | 49 | 105 | 69 |
| 10 | ↊ | 42 | 2↊ | 74 | 4↊ | 106 | 6↊ |
| 11 | ↋ | 43 | 2↋ | 75 | 4↋ | 107 | 6↋ |
| 12 | ↉ | 44 | 2↉ | 76 | 4↉ | 108 | 6↉ |
| 13 | ↈ | 45 | 2ↈ | 77 | 4ↈ | 109 | 6ↈ |
| 14 | ↇ | 46 | 2ↇ | 78 | 4ↇ | 110 | 6ↇ |
| 15 | ↆ | 47 | 2ↆ | 79 | 4ↆ | 111 | 6ↆ |
| 16 | 10 | 48 | 30 | 80 | 50 | 112 | 70 |
| 17 | 11 | 49 | 31 | 81 | 51 | 113 | 71 |
| 18 | 12 | 50 | 32 | 82 | 52 | 114 | 72 |
| 19 | 13 | 51 | 33 | 83 | 53 | 115 | 73 |
| 20 | 14 | 52 | 34 | 84 | 54 | 116 | 74 |
| 21 | 15 | 53 | 35 | 85 | 55 | 117 | 75 |
| 22 | 16 | 54 | 36 | 86 | 56 | 118 | 76 |
| 23 | 17 | 55 | 37 | 87 | 57 | 119 | 77 |
| 24 | 18 | 56 | 38 | 88 | 58 | 120 | 78 |
| 25 | 19 | 57 | 39 | 89 | 59 | 121 | 79 |
| 26 | 1↊ | 58 | 3↊ | 90 | 5↊ | 122 | 7↊ |
| 27 | 1↋ | 59 | 3↋ | 91 | 5↋ | 123 | 7↋ |
| 28 | 1↉ | 60 | 3↉ | 92 | 5↉ | 124 | 7↉ |
| 29 | 1ↈ | 61 | 3ↈ | 93 | 5ↈ | 125 | 7ↈ |
| 30 | 1ↇ | 62 | 3ↇ | 94 | 5ↇ | 126 | 7ↇ |
| 31 | 1ↆ | 63 | 3ↆ | 95 | 5ↆ | 127 | 7ↆ |
| 32 | 20 | 64 | 40 | 96 | 60 | 128 | 80 |

TABLE I.—CONTINUED.

*Notation of Tonal and Decimal Numbers.*

| Decimal. | Tonal. | Decimal. | Tonal. | Decimal. | Tonal. | Decimal. | Tonal. |
|---|---|---|---|---|---|---|---|
| 129 | 81 | 161 | 91 | 193 | ᘐ1 | 225 | ᘑ1 |
| 130 | 82 | 162 | 92 | 194 | ᘐ2 | 226 | ᘑ2 |
| 131 | 83 | 163 | 93 | 195 | ᘐ3 | 227 | ᘑ3 |
| 132 | 84 | 164 | 94 | 196 | ᘐ4 | 228 | ᘑ4 |
| 133 | 85 | 165 | 95 | 197 | ᘐ5 | 229 | ᘑ5 |
| 134 | 86 | 166 | 96 | 198 | ᘐ6 | 230 | ᘑ6 |
| 135 | 87 | 167 | 97 | 199 | ᘐ7 | 231 | ᘑ7 |
| 136 | 88 | 168 | 98 | 200 | ᘐ8 | 232 | ᘑ8 |
| 137 | 85 | 169 | 95 | 201 | ᘐ5 | 233 | ᘑ5 |
| 138 | 89 | 170 | 99 | 202 | ᘐ9 | 234 | ᘑ9 |
| 139 | 8ᘔ | 171 | 9ᘔ | 203 | ᘐᘔ | 235 | ᘑᘔ |
| 140 | 8ᘐ | 172 | 9ᘐ | 204 | ᘐᘐ | 236 | ᘑᘐ |
| 141 | 8ᘓ | 173 | 9ᘓ | 205 | ᘐᘓ | 237 | ᘑᘓ |
| 142 | 8ᘑ | 174 | 9ᘑ | 206 | ᘐᘑ | 238 | ᘑᘑ |
| 143 | 8ᘏ | 175 | 9ᘏ | 207 | ᘐᘏ | 239 | ᘑᘏ |
| 144 | 50 | 176 | ᘔ0 | 208 | ᘓ0 | 240 | ᘏ0 |
| 145 | 51 | 177 | ᘔ1 | 209 | ᘓ1 | 241 | ᘏ1 |
| 146 | 52 | 178 | ᘔ2 | 210 | ᘓ2 | 242 | ᘏ2 |
| 147 | 53 | 179 | ᘔ3 | 211 | ᘓ3 | 243 | ᘏ3 |
| 148 | 54 | 180 | ᘔ4 | 212 | ᘓ4 | 244 | ᘏ4 |
| 149 | 55 | 181 | ᘔ5 | 213 | ᘓ5 | 245 | ᘏ5 |
| 150 | 56 | 182 | ᘔ6 | 214 | ᘓ6 | 246 | ᘏ6 |
| 151 | 57 | 183 | ᘔ7 | 215 | ᘓ7 | 247 | ᘏ7 |
| 152 | 58 | 184 | ᘔ8 | 216 | ᘓ8 | 248 | ᘏ8 |
| 153 | 55 | 185 | ᘔ5 | 217 | ᘓ5 | 249 | ᘏ5 |
| 154 | 59 | 186 | ᘔ9 | 218 | ᘓ9 | 250 | ᘏ9 |
| 155 | 5ᘔ | 187 | ᘔᘔ | 219 | ᘓᘔ | 251 | ᘏᘔ |
| 156 | 5ᘐ | 188 | ᘔᘐ | 220 | ᘓᘐ | 252 | ᘏᘐ |
| 157 | 5ᘓ | 189 | ᘔᘓ | 221 | ᘓᘓ | 253 | ᘏᘓ |
| 158 | 5ᘑ | 190 | ᘔᘑ | 222 | ᘓᘑ | 254 | ᘏᘑ |
| 159 | 5ᘏ | 191 | ᘔᘏ | 223 | ᘓᘏ | 255 | ᘏᘏ |
| 160 | 90 | 192 | ᘐ0 | 224 | ᘑ0 | 256 | 100 |

TABLE II.

*Notation of Tonal and Decimal Numbers.*

| Decimal. | Tonal. | Decimal. | Tonal. | Decimal. | Tonal. |
|---|---|---|---|---|---|
| 100 | 64 | 100,000 | 1,8690 | 3,584 | ℨ00 |
| 200 | ℣8 | 200,000 | 3,0ℰ40 | 3,840 | ℓ00 |
| 300 | 12ℓ | 300,000 | 4,5ℰℨ0 | 4,096 | 1000 |
| 400 | 150 | 400,000 | 6,1980 | 8,192 | 2000 |
| 500 | 1ℓ4 | 500,000 | 7,9120 | 12,288 | 3000 |
| 600 | 258 | 600,000 | 5,27ℨ0 | 16,384 | 4000 |
| 700 | 2ℰ℣ | 700,000 | 9,9ℨ60 | 20,480 | 5000 |
| 800 | 320 | 800,000 | ℣,3500 | 24,576 | 6000 |
| 900 | 384 | 900,000 | ℰ,ℰ290 | 28,672 | 7000 |
| 1,000 | 3ℨ8 | 1,000,000 | ℓ,4240 | 32,678 | 8000 |
| 2,000 | 7ℰ0 | 2,000,000 | 1ℨ,8480 | 36,864 | 5000 |
| 3,000 | ℰℰ8 | 3,000,000 | 2ℰ,ℓ6ℓ0 | 40,960 | 9000 |
| 4,000 | ℓ90 | 4,000,000 | 3ℰ,0500 | 45,056 | ℣000 |
| 5,000 | 1388 | 256 | 100 | 49,152 | ℣000 |
| 6,000 | 1770 | 512 | 200 | 52,348 | ℰ000 |
| 7,000 | 1ℰ58 | 768 | 300 | 57,344 | ℨ000 |
| 8,000 | 2040 | 1,024 | 400 | 61,440 | ℓ000 |
| 9,000 | 23℣8 | 1,280 | 500 | 65,536 | 1,0000 |
| 10,000 | 2710 | 1,530 | 600 | 262,144 | 4,0000 |
| 20,000 | 4ℨ20 | 1,792 | 700 | 524,288 | 8,0000 |
| 30,000 | 7530 | 2,048 | 800 | 786,432 | ℣,0000 |
| 40,000 | 5ℰ40 | 2,304 | 500 | 1,048,576 | ℓ,0000 |
| 50,000 | ℣550 | 2,560 | 900 | 16,777,216 | 10,0000 |
| 60,000 | ℨ960 | 2,816 | ℰ00 | 268,435,456 | 100,0000 |
| 70,000 | 1,1170 | 3,072 | ℣00 | 3,489,767,296 | 1000,0000 |
| 80,000 | 1,3880 | 3,320 | ℰ00 | 55,736,276,736 | 1,0000,0000 |
| 90,000 | 1,5ℓ50 | | | | |

TABLE III.

*Vulgar Fractions, Tonals, and Decimals.*

| Decimal. | Tonal. | Decimal. | Tonal. |
|---|---|---|---|
| $\frac{1}{2}=0{\cdot}5$ | $\frac{1}{2}=0{\cdot}8$ | $\frac{11}{16}=0{\cdot}6875$ | $\frac{8}{10}=0{\cdot}8$ |
| $\frac{1}{4}=0{\cdot}25$ | $\frac{1}{4}=0{\cdot}4$ | $\frac{13}{16}=0{\cdot}8125$ | $\frac{8}{10}=0{\cdot}8$ |
| $\frac{1}{8}=0{\cdot}125$ | $\frac{1}{8}=0{\cdot}2$ | $\frac{15}{16}=0{\cdot}9375$ | $\frac{9}{10}=0{\cdot}9$ |
| $\frac{3}{4}=0{\cdot}75$ | $\frac{3}{4}=0{\cdot}\mathcal{U}$ | $\frac{1}{32}=0{\cdot}03125$ | $\frac{1}{20}=0{\cdot}08$ |
| $\frac{3}{8}=0{\cdot}375$ | $\frac{3}{8}=0{\cdot}6$ | $\frac{7}{24}=0{\cdot}29166..$ | $\frac{7}{18}=0{\cdot}4999..$ |
| $\frac{5}{8}=0{\cdot}625$ | $\frac{5}{8}=0{\cdot}9$ | $\frac{5}{12}=0{\cdot}4166..$ | $\frac{5}{9}=0{\cdot}6999..$ |
| $\frac{7}{8}=0{\cdot}875$ | $\frac{7}{8}=0{\cdot}\mathcal{Z}$ | $\frac{1}{3}=0{\cdot}3333..$ | $\frac{1}{3}=0{\cdot}5555..$ |
| $\frac{1}{16}=0{\cdot}0625.$ | $\frac{1}{10}=0{\cdot}1$ | $\frac{2}{3}=0{\cdot}6666..$ | $\frac{2}{3}=0{\cdot}9999..$ |
| $\frac{3}{16}=0{\cdot}1875$ | $\frac{3}{10}=0{\cdot}3$ | $\frac{1}{6}=0{\cdot}1666..$ | $\frac{1}{6}=0{\cdot}2999..$ |
| $\frac{5}{16}=0{\cdot}3125$ | $\frac{5}{10}=0{\cdot}5$ | $\frac{1}{64}=0{\cdot}015625$ | $\frac{1}{40}=0{\cdot}04$ |
| $\frac{7}{16}=0{\cdot}4375$ | $\frac{7}{10}=0{\cdot}7$ | $\frac{25}{64}=0{\cdot}380625$ | $\frac{14}{40}=0{\cdot}64$ |
| $\frac{9}{16}=0{\cdot}5625$ | $\frac{5}{10}=0{\cdot}5$ | $\frac{1}{128}=0{\cdot}0078125$ | $\frac{1}{80}=0{\cdot}02$ |

TABLE IV.

*Addition and Subtraction. Tonal System.*

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 5 | 9 | ɤ | ɐ | ɛ | ƨ | ɬ | 10 |
| 2 | 4 | 5 | 6 | 7 | 8 | 5 | 9 | ɤ | ɐ | ɛ | ƨ | ɬ | 10 | 11 | 12 |
| 3 | 5 | 6 | 7 | 8 | 5 | 9 | ɤ | ɐ | ɛ | ƨ | ɬ | 10 | 11 | 12 | 13 |
| 4 | 6 | 7 | 8 | 5 | 9 | ɤ | ɐ | ɛ | ƨ | ɬ | 10 | 11 | 12 | 13 | 14 |
| 5 | 7 | 8 | 5 | 9 | ɤ | ɐ | ɛ | ƨ | ɬ | 10 | 11 | 12 | 13 | 14 | 15 |
| 6 | 8 | 5 | 9 | ɤ | ɐ | ɛ | ƨ | ɬ | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 7 | 5 | 9 | ɤ | ɐ | ɛ | ƨ | ɬ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 8 | 9 | ɤ | ɐ | ɛ | ƨ | ɬ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 5 | ɤ | ɐ | ɛ | ƨ | ɬ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 15 |
| 9 | ɐ | ɛ | ƨ | ɬ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 15 | 19 |
| ɤ | ɛ | ƨ | ɬ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 15 | 19 | 1ɤ |
| ɐ | ƨ | ɬ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 15 | 19 | 1ɤ | 1ɐ |
| ɛ | ɬ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 15 | 19 | 1ɤ | 1ɐ | 1ɛ |
| ƨ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 15 | 19 | 1ɤ | 1ɐ | 1ɛ | 1ƨ |
| ɬ | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 15 | 19 | 1ɤ | 1ɐ | 1ɛ | 1ƨ | 1ɬ |
| 10 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 15 | 19 | 1ɤ | 1ɐ | 1ɛ | 1ƨ | 1ɬ | 20 |

TABLE V.

*Multiplication and Division. Tonal System.*

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 5 | 9 | ɤ | ɐ | ɛ | ƨ | ɬ | 10 |
| 2 | 4 | 6 | 8 | 9 | ɐ | ƨ | 10 | 12 | 14 | 16 | 18 | 19 | 1ɐ | 1ƨ | 20 |
| 3 | 6 | 5 | ɐ | ɬ | 12 | 15 | 18 | 1ɤ | 1ƨ | 21 | 24 | 27 | 29 | 2ɛ | 30 |
| 4 | 8 | ɐ | 10 | 14 | 18 | 1ɐ | 20 | 24 | 28 | 2ɐ | 30 | 34 | 38 | 3ɐ | 40 |
| 5 | 9 | ɬ | 14 | 15 | 1ƨ | 23 | 28 | 2ɛ | 32 | 37 | 3ɐ | 41 | 46 | 4ɤ | 50 |
| 6 | ɐ | 12 | 18 | 1ƨ | 24 | 29 | 30 | 36 | 3ɐ | 42 | 48 | 4ƨ | 54 | 59 | 60 |
| 7 | ƨ | 15 | 1ɐ | 23 | 29 | 31 | 38 | 3ɬ | 46 | 4ɛ | 54 | 5ɤ | 62 | 65 | 70 |
| 8 | 10 | 18 | 20 | 28 | 30 | 38 | 40 | 48 | 50 | 58 | 60 | 68 | 70 | 78 | 80 |
| 5 | 12 | 1ɤ | 24 | 2ɛ | 36 | 3ɬ | 48 | 51 | 59 | 63 | 6ɐ | 75 | 7ƨ | 87 | 50 |
| 9 | 14 | 1ƨ | 28 | 32 | 3ɐ | 46 | 50 | 59 | 64 | 6ƨ | 78 | 82 | 8ɐ | 56 | 90 |
| ɤ | 16 | 21 | 2ɐ | 37 | 42 | 4ɛ | 58 | 63 | 6ƨ | 75 | 48 | 8ɬ | 59 | 95 | ɤ0 |
| ɐ | 18 | 24 | 30 | 3ɐ | 48 | 54 | 60 | 6ɐ | 78 | 84 | 50 | 3ɐ | 98 | ɤ4 | ɐ0 |
| ɛ | 19 | 27 | 34 | 41 | 4ƨ | 5ɤ | 68 | 75 | 82 | 8ɬ | 5ɐ | 99 | ɤ6 | ɐ3 | ɛ0 |
| ƨ | 1ɐ | 29 | 38 | 46 | 54 | 62 | 70 | 7ƨ | 8ɐ | 59 | 98 | ɤ6 | ɐ4 | ɛ2 | ƨ0 |
| ɬ | 1ƨ | 23 | 3ɐ | 4ɤ | 59 | 65 | 78 | 87 | 56 | 95 | ɤ4 | ɐɐ | ɛ2 | ƨ1 | ɬ0 |
| 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 50 | 90 | ɤ0 | ɐ0 | ɛ0 | ƨ0 | ɬ0 | 100 |

TABLE III is an excellent illustration of the utility of the *tonal system*. It contains the ordinary fractions used in the shop and the market. It will be seen that the vulgar fractions in daily use, require four to seven decimals, where the *tonal system* require only one or two figures. It must be admitted that it is more natural to divide

things into halves, quarters, eighths or sixteenths, than into fifths or tenths, and when the natural fractions are expressed by decimals, they become too complicated for the ordinary uneducated mind, as $\frac{3}{16}$ is equal to 0·1875, which cannot be conceived by the very best arithmeticians, but they know by practice in calculation that it is so. In the *tonal system* it is very easy to conceive that $\frac{3}{16}$ is equal to 0·3.

TABLE IV is for addition and subtraction, arranged in the ordinary way, that where the vertical and horizontal columns cross one another is the sum of the index numbers.

EXAMPLE 4. $3+5=8$, $5+9=\mathfrak{f}$, and $\mathfrak{v}+\mathfrak{z}=15$.

For subtraction, find the greatest number in the column in which the smaller number is the index, and the index of the cross column is the difference, as $17-\mathfrak{v}=\mathfrak{v}$.

ADDITION.

Ex. 5.

| | |
|---|---|
| To | 36ɤ9ʒ |
| Add | 10578 |
| Same | 47526 |

$\mathfrak{z}+8=16$
$9+7=11$.
$\mathfrak{v}+5=14$..
$6+0=6$ ...
$3+1=4$ ....
47526

Ex. 6.

| | |
|---|---|
| | 89f5 |
| | 45ʒɤ |
| | 308 |
| | ɛ3ʒ$\mathfrak{v}$ |

$5+\mathfrak{v}+8=1\mathfrak{v}$
$\mathfrak{f}+\mathfrak{z}+0=1\mathfrak{ɛ}$
$9+5+3=12$
$4+8=\mathfrak{v}$
$\mathfrak{v}$3ʒɛ

Ex. 7.

| | |
|---|---|
| | 3819·ɛf |
| | 6ɤ0·01 |
| | f3·34 |
| | 0·03 |
| | 0·49 |
| | 3f$\mathfrak{v}$8·61 |

Ex. 8.

| | |
|---|---|
| | 67850 |
| | ɤɛ0$\mathfrak{v}$ |
| | 945 |
| | 9f |
| | $\mathfrak{z}$ |
| | 7405$\mathfrak{z}$ |

SUBTRACTION.

Ex. 5.

| | |
|---|---|
| From | 38ʒ9f |
| Subt. | 4ɤ53 |
| Diff. | 3431$\mathfrak{v}$ |

Ex. 9.

| | |
|---|---|
| + | 8104ʒɤ |
| — | 4250f |
| | 7$\mathfrak{v}$ɛɤɛ$\mathfrak{v}$ |

Ex. ɤ.

| | |
|---|---|
| + | 89ɤɛ0·01f |
| — | ʒ00f·301 |
| | 7$\mathfrak{v}$ɤɤ0·ɛ1ʒ |

In all arithmetical operations, the *tonal fractions* work precisely the same as *decimal fractions*.

TABLE V is an ordinary arranged multiplication table.

MULTIPLICATION.

Ex. 7.

| | |
|---|---|
| 38916 | $6\times6=24$ |
| 6 | $6\times7=42$. |
| | $6\times9=37$.. |
| | $6\times8=30$... |
| 154044 | $6\times3=12$.... |
| | 154044 |

Ex. 8.

| | |
|---|---|
| 80549 | |
| 72 | |
| 101344 | |
| 384586 | |
| 3547154 | |

Ex. 9.

| | |
|---|---|
| 38720644 | |
| 0·00684 | |
| 272815537 | |
| 17534103278. | |
| 154742589.. | |
| 1717·6211957 | |

DIVISION.

Ex. 6.

3 | 189772 | 835549·99
18.....
09....
5....
17...
17...
17..

Ex. 10.

172 | 4783930087 | 29077·65·13393
394.....
1249....
1234....
1650..
1588..
780

*Table of Tonal Logarithms.*

| Number. | Logarithm. | Number. | Logarithm. |
|---|---|---|---|
| 1 | 0·0 | 5 | 0·77 |
| 2 | 0·4 | 9 | 0·84 |
| 3 | 0·66 | 7 | 0·88 |
| 4 | 0·8 | 7 | 0·96 |
| 5 | 0·54 | 8 | 0·92 |
| 6 | 0·96 | 6 | 0·64 |
| 7 | 0·74 | 4 | 0·47 |
| 8 | 0·7 | 10 | 1·00 |

This table of *tonal logarithms* is a good illustration of the simplicity of the system. In logarithms for single figures, the montissa contains only one or two *tonals*, where the decimal system has a tail of an endless number of decimals.

The Tonal multiplication table extends two and a half-times further than the decimal one, still, the latter is about that much more difficult to learn than the former, owing to the natural location of aliquot numbers in the tonal base; for instance, 6 times 8 is 48 decimal, which must be learnt by heart, but in the tonal system we know that 8 is half the base, and half of 6 is 3, or three times the base, $6 \times 8 = 30$.

Decimal $12 \times 12 = 144$, which is known by practice in calculation or by regular multiplication, but in the tonal system we know that twelve, which is denoted by *v*, is $\frac{3}{4}$ of the base, and $\frac{3}{4}$ of twelve is nine, denoted by 9, or $v \times v = 90$.

It is surprising to know to what extent and readiness mental calculation can be performed by the tonal system: for ordinary purposes in the shop and the market, slate and pencil would rarely be necessary. The writer often performs calculations in the tonal system, and transfers the result to decimal arithmetic.

The apparent difficulty of learning and introducing the tonal system, would soon be removed when once started, for the people would pick it up sooner than the accomplished arithmeticians, on account of it being natural to the mind, which will be further explained in the tonal metrology.

When we attempt to introduce the unnatural decimal system, why should we hesitate to bring forward that which is natural to the mind?

(To be continued on Tontal Metrology.)

---

## *The Golden Parallels.*

From the Journal of the Society of Arts, No. 560.

In the late number of the *Edinburgh Review*, there is a notice of several publications on the subject of gold fields and gold miners. A mass of facts is collected relative to the Australian, California, and Columbian gold diggings, and several important conclusions are arrived at. In the first place, we are reminded that the great gold fields already discovered are all included within two regions. The gold fields of New South Wales and Victoria extend without any interruption along the slopes of the great mountain range which separates the eastern seaboard of Australia from the interior of the continent, and the gold fields of California and British Columbia occur without interruption along the western slopes of the Rocky Mountains. Thus, there are presented two great gold-bearing regions, extending along two widely distant elevations, and probably "owing their auriferous character to some influence connected with the upheaval." The possibility of establishing a connexion between these two gold-bearing regions will be understood after a little consideration of their charac-

teristics. The American gold fields, under various names, run along the eastern seaboard of the Pacific, almost from pole to pole—from Behring's Straits in the north to Cape Horn in the south. Throughout this vast region large quantities of the precious metal are found. "From Chili, in the south, to the British Possessions, in the north, its slopes, spurs, and subordinate ranges are now yielding gold. From Chili we mount through Bolivia, Peru, Equador, New Granada, all still continuing to yield the precious metal, after some three centuries of gold mining. Thence, after we pass the Isthmus, we find the gold miner at work through Mexico, California, Oregon, Washington, till at length we come to the British Possessions, stretching to the shores of the Arctic Ocean." Such is a brief description of the gold-bearing system of America. Turning now to that of Australia, there is found a coast range running from the extreme northern point of the continent to the extreme southern point. But this range neither begins nor terminates in Australia. It extends across Bass' Straits, on the one hand, and beyond Cape York on the other; in which direction the chain of rocks forms at intervals numerous islands, such as New Guinea, the Carolines, the Ladrones, and others, until Japan, with its gold-bearing rocks, is reached. Thus, in accordance with this theory, the basin of the Pacific has on each side a continuous elevation of volcanic origin. At intervals on both sides gold is now found, from Behring's Straits to New Zealand; and it is stated that at the "beach diggings" in California, a blush sand, not unlike the pipe clay of Ballarat, is frequently thrown up by the waves, and is found to contain gold in considerable quantities.

The conclusion arrived at by this reasoning is that the great gold fields of the world, as at present known, are included in the vast system of volcanic rocks which surround the Pacific. This chain, though broken here and there, is said to be traceable between Australia and America, and to be easy of identification on both sides of the ocean. Such a continuous and well-marked line of volcanic elevation has often received the attention of geologists. Humboldt's view, which is the one generally accepted on the subject, is that the bed of the Pacific attained its present depth at a comparatively late period: that its unbroken crust, pressed down on the molten mass underneath, caused a quantity of it to rush towards the line of fracture at the edges, and that this disturbed matter found vent in the elevations which are now connected with the gold fields of America and Australia. So far these considerations, as bearing on the science of geology, are highly important; but it has to be shown in what way gold is to be connected with volcanic shocks in some places and not in others. On this point it is to be laid down by Sir Roderick Murchison that the rocks which are the most auriferous are of the Silurian age, and that a certain geological zone only in the crust of the globe is auriferous at all. Gold, he states, has never been found in any stratified formations composed of secondary or tertiary deposits, but only in cyrstalline and palæozoic rocks, or in the drift from those rocks. The most usual original position of the metal is in quartzose veinstones

that traverse altered Silurian slates, frequently near their junction with eruptive rocks. Sometimes, however, it is partially diffused through the body of rocks of igneous origin. From this it appears that volcanic eruptions, in connexion with Silurian rocks, are to be regarded as the origin of gold formations.

It will have been seen that, according to the volcanic basin theory as described above, the auriferous rocks which surround the Pacific leave Victoria and plunge into the sea to appear again on the other side of Bass's Straits. This would, of course, leave South Australia out of the reach of these gold bearing ranges. But singularly enough, the reviewer, after remarking upon this termination of the Victorian rocks, refers to the geological work of Mr. Julian Woods in order to show a curious extension of the volcanic action which is to be "traced in South Australia." On referring to the extract, however, it appears that Mr. Woods' reference is not to South Australia, although it relates to the country close upon its border. Mr. Woods says:—"At about fifty miles east of Mount Gambier, on the Victorian side of the boundary, there commences an immense volcanic district, which may be traced with very little interruption to Geelong by immense masses of trap rock and extinct craters of large dimensions. This kind of country extends considerably to the north of the line, and it is underneath the trap rocks there found at the junction of the Silurian slates and ancient granites that the extensive Australian gold-fields are worked."

Another extract is given from Mr. Woods' book, embodying a statement similar to that which has been already quoted from Sir Roderick Murchison, namely, that trap rock and other indications of volcanic eruption are no guide to the presence of gold, unless in the neighborhood of Silurian rocks.

---

For the Journal of the Franklin Institute.

## *Austrian Gun Metal.*

In the *Chemical News*, No. 167, will be found an account, (since published in the *Journal of the Franklin Institute*, May number, 1863, page 349,) and also in the *Artizan* for January, 1863, credited to an unnamed contemporary, of the new alloy, "sterrometal," discovered by Baron Von Rosthorn, of Austria, and tested at the Imperial Arsenal, and at the Polytechnic Institute, with such remarkable results as to make it well worthy the attention of metallurgists. Its cost, compared with that of ordinary gun metal, is moderate, due to the small proportion of tin and large per centage of spelter composing it.

This, with its great tensile strength, makes the metal applicable for many purposes, besides that of gun making, where wrought iron of complicated shape and expensive manufacture is now used, and where it is of importance to avoid rapid oxidation. For example, hollow piston rods and cylinder covers for inverted steam hammers, pistons for quick moving engines, chain cables, rudder posts and stocks, pump rods, holding down bolts for marine engines, propellers, &c.

In order to test its qualifications and fitness for their uses, Messrs. Merrick & Sons prepared and tested a number of pieces, cast with varied conditions and proportions, together with some of the best gun metal, in order to make a comparison. The proportions, conditions, and results, are as follows :—

| Proportions of | | Copper. | Spelter. | Tin. | Iron. | Conditions. |
|---|---|---|---|---|---|---|
| Formulæ Polytechnic Institute. | Specimens, Nos. 1 and 2, | 55·04 | 42·36 | ·83 | 1·77 | New Materials, |
| | " Nos. 3 and 4, | " | " | " | " | Run into ingots, and Remelted. |
| Formulæ Imperial Arsenal. | " Nos. 5 and 6, | 57·63 | 40·22 | ·15 | 1·86 | New Materials, |
| | " Nos. 7 and 8, | " | " | " | " | Run into ingots, and Remelted. |
| Formulæ Artizan. | " Nos. 9 and 10, | 57·97 | 37·68 | 1·45 | 2·9 | New Materials, |
| | " Nos. 11 and 12, | " | " | " | " | Run into ingots, and Remelted. |
| Formulæ ordinary gun metal. | " Nos. 13 and 14, | 89· | 1·5 | 9·5 | . . | New Materials, |
| | " Nos. 15 and 16, | " | " | " | . . | Run into ingots, and Remelted. |

All the pieces were cast but little larger in diameter than ·75 of an inch, so that a small portion only of the outside was required to be turned off to make them of the given diameter, and a large sinking head used to give solidity.

| Number of specimens. | Original diameter. | Original area. | Breaking diameter. | Breaking area. | Breaking weight. | Breaking weight per square inch. Original area. | Breaking weight per square inch. Breaking area. | Mean Breaking weight per square inch. Original area. | Mean Breaking weight per square inch. Breaking area. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ·755 | ·4476 | ·724 | ·4116 | 27500 | 61439 | 66812 | . . | . . |
| 2 | ·755 | ·4476 | ·714 | ·4002 | 28000 | 62555 | 69900 | 61997 | 68356 |
| 3 | ·742 | ·4323 | ·685 | ·3658 | 24500 | 56673 | 66976 | . . | . . |
| 4 | ·765 | ·4596 | ·720 | ·4071 | 26700 | 58094 | 65585 | 57383 | 66280 |
| 5 | ·76 | ·4536 | ·75 | ·4417 | 23500 | 51807 | 53203 | . . | . . |
| 6 | ·763 | ·4571 | ·723 | ·4107 | 25500 | 55786 | 62089 | 53796 | 57646 |
| 7 | ·765 | ·4596 | ·696 | ·3802 | 23000 | 50043 | 60495 | . . | . . |
| 8 | ·753 | ·4453 | ·692 | ·3760 | 23875 | 53615 | 60350 | 51829 | 60422 |
| 9 | ·762 | ·456 | ·726 | ·4139 | 21625 | 47423 | 52244 | . . | . . |
| 10 | ·763 | ·4571 | ·740 | ·4300 | 22750 | 49770 | 52907 | 48596 | 52525 |
| 11 | ·762 | ·456 | ·663 | ·3451 | 21000 | 46052 | 60851 | . . | . . |
| 12 | ·765 | ·4596 | ·744 | ·4347 | 21500 | 46779 | 49459 | 46415 | 55155 |
| 13 | ·762 | ·456 | ·688 | ·3717 | 20500 | 44956 | 55152 | . . | . . |
| 14 | ·765 | ·4596 | ·652 | ·3338 | 18500 | 40252 | 55422 | 42604 | 55287 |
| 15 | ·751 | ·4429 | ·730 | ·4185 | 19000 | 42900 | 45400 | . . | . . |
| 16 | ·762 | ·456 | ·687 | ·3706 | 20500 | 44956 | 55316 | 43928 | 50358 |

Specimens Nos. 1, 2, 3, and 4 have a jagged rupture, revealing some dull crystals, lying parallel with plane of separation, and at right angles to surfaces first cooled. Their color is of a rich yellow.

The metals do not appear to have incorporated, small specks of a lighter color being interspersed. The remelting with the expectation of obtaining greater tensile strength by a more thorough mixing, did not produce that effect, but the contrary, as shown by comparing the mean strength of Nos. 1 and 2 with that of Nos. 3 and 4; a loss of about 3 per cent.

Specimens Nos. 5, 6, 7, and 8 are soft and ductile. The first piece of this composition had its least diameter 1 inch, and whilst being tested, the collar on one end yielded, and was drawn out of the clamp, the end assuming a cup shape. Its diameter was reduced subsequently to give the collars a greater proportionate bearing to section of rupture. Its fracture has a close fibrous appearance, with some granules about the axis. The general surface of rupture is not that of least section—at right angles to axis—but, is at an angle of about 25° to it. In this case a remelting increased the tenacity about 4·8 per cent. The color of this composition is not nearly so rich as that of Nos. 1 and 2, but is of a pale yellow, resembling common brass.

Specimens Nos. 9, 10, 11, and 12 are composed according to the formulæ given in the *Artizan*, with the spelter, tin, and iron, about in the mean proportion of the ranges given for those ingredients. The tin and iron are largely increased over the proportions required by both the other formulas, and, as might be anticipated, increased hardness results.

Their structure is granular and very close. The plane of separation is nearly at right angles to axis of piece, and somewhat jagged. In this composition a remelting produced a gain in tenacity of a little over 5 per cent.

Specimens Nos. 13, 14, 15, and 16 are of the ordinary gun metal composition, with the small portion of spelter added to insure sound castings. The remelting shows a loss of strength amounting to nearly 9 per cent.

All the materials used were new and melted in fresh crucibles.

Their values for tensile strains are about in the order they stand, the last two having very little difference between best results. No doubt a difference in quantities of spelter, tin, and iron would have increased the tenacity of Nos. 9 and 10, but the trial was not made; the results obtained showing that the metal was equal to ordinary wrought iron, whilst its greater hardness compensated for lesser tenacity. J.

---

For the Journal of the Franklin Institute.

## *Strength Combined with Economy of Material in Constructing the Details of Steam Engines.* By R. H. Thurston, U. S. N.

On page 47, of the *Journal* for July, I noticed a sketch of a form of piston recommended as combining strength with economy of material; but neither in that article nor elsewhere do I remember having found a rule, or a formula, by which to determine the proper thickness of metal for that most important detail of the steam engine.

In the absence of authority on the subject, I have worked out a formula, that, I think, gives ample strength and great economy of material.

Considering the action of the steam on the piston, but a moment's thought is required to prove that the piston may be made much thinner at the circumference, than at the centre.

The circular section immediately around the rod is compelled to sustain a shearing strain equal to the whole pressure exerted on the piston, while at the circumference, it might be brought to an edge, except that the arrangement of packing rings, and the strains that they are liable to cause, compel us to modify that form.

Let D = Diameter of cylinder in inches.
$d$ = " " circle on which thickness is required, in inches.
$t$ = Thickness required (in inches) of metal on circle of diam. $d$.
$p$ = Pressure of steam vacuum (maximum) in lbs. per sq. inch.

$$\text{Then } t = \frac{(D^2 - d^2)\,p}{6000\,d} + \frac{D}{80}$$

In the case of a piston made with a single solid disk, after finding the thickness of section on three or four concentric circles, a curve may be struck through them, determining the form of the piston. For the usual hollow piston, $\frac{t}{2}$ is the proper thickness of each disk; or it may be slightly reduced to compensate for the extra strength given by the ribs inside it. For Mr. Nystrom's form of piston, increase the divisor as the curvature is increased.

I think the above a good formula for general use, and I find it effects a considerable saving in weight over a majority of forms usually given.

Any manufacturing engineer, having tried a similar, or any other rule for dimensions of details of engines, would confer a favor on the profession by making public the result of his trial. In a majority of these details, even recognised authorities differ so widely that none can be accepted as correct, and different manufacturers vary quite as widely in their practice.

The following formulæ were first given, as I conceived a correct form theoretically, and then corrected by comparison with similar parts of engines by our best builders, and particularly with cases that have come to my knowledge where fracture has occurred.

*For Piston Rods.*

Let D = Diameter of cylinder in inches.

$d$ = " rod " $d = \sqrt[4]{\frac{D^2 l^2 p}{10000}} + \frac{1}{4}$

$l$ = Length of stroke in feet.
$p$ = Pressure (maximum) in lbs. per sq. inch.

For screw engines divide by 4000 instead of 10000.

*For Thickness Cylinder Heads.*

Let D = Diameter of circle at which the thickness is required.
$t$ = Thickness in inches of metal in the head on circle of diameter D.
$p$ = Pressure (maximum) in lbs. per sq. inch.

$$t = \frac{D\,p}{3000} + \frac{1}{2}$$

I hope other engineers may be able to present other unpublished formulæ of greater value than the above.

Port Royal, S. C., September, 1863.

---

## FRANKLIN INSTITUTE.

*Proceedings of the Stated Monthly Meeting, Sept.* 17, 1863.

James Dougherty, President, pro tem., in the Chair.

Isaac B. Garrigues, Recording Secretary.

The minutes of the last meeting were read and approved.

Donations to the Library were received from the Royal Geographical Society, the Institute of Actuaries, and the Society of Arts, London; the Natural History Society, Montreal, Canada; Prof. A. Dallas Bache, Superintendent U. S. Coast Survey, and the U. S. Agricultural Bureau, Washington, D. C.; Prof. Wm. Chauvenet, St. Louis, Mo.; the Chamber of Commerce, City of New York; the Regents of the University of the State of New York, Albany, N. Y.; Robert C. Bacot, Esq., Jersey City, New Jersey; and the Union League, Philadelphia.

A Donation to the Cabinet of Minerals was received from John Hoskins, Esq., Philadelphia.

The Periodicals received in exchange for the Journal of the Institute were laid on the table.

The Treasurer's statement of the receipts and payments for the month of August was read.

The Board of Managers and Standing Committees reported their minutes.

Candidates for membership in the Institute (7) were proposed, and those (4) proposed at the last meeting were duly elected.

Mr. John W. Nystrom exhibited some French metres, and said—

I have brought to the meeting this evening some specimens of the French metre, with a view of discussing the metrical system, which is now, against great resistance, gaining ground in Europe, and is proposed to be adopted in England, and finally in America. The French metrical system was originated about 70 years ago, when MM. Delambre and Mèchain measured an arc of a meridian between the parallels of Dunkirk and Barcelona, a distance of 32,808,992 English feet, from which the length of the quadrant of the earth from the equator to the

north pole was calculated, and subsequently divided repeatedly by the arithmetical base 10, until a suitable unit of length was attained. The quadrant divided into ten million parts gave a length of about 40 English inches, which was adopted as a unit and called a *metre*, in appearance as you here see. The length of the earth's quadrant should therefore be 10,000,000 metres, but owing to the incorrectness of mathematical instruments in those days, the angles and base lines in the triangulation between Dunkirk and Barcelona could not be so correctly measured as desired for such an important purpose; neither were the calculations correctly applied, for want of very important formulas for correction, subsequent measurement and calculation having proved the quadrant to be 10,000,856 metres, or 856 metres longer, which makes the adopted metre too short. The definitive length of the metre was fixed at 443,296 lines, equivalent, by subsequent experiments of the French Academy, to 39·382 English inches; experiments by Captain Kater, 39·37079 inches; by Mr. Hassler, of this country, 39·3802; and a more recent American authority, the U. S. Coast Survey, under the superintendence of Prof. Bache, has calculated the French metre to be 39·3685 inches; which latter is likely at the present time to be the most correct length of metre, for the instruments used by the Coast Survey are far superior to those of MM. Delambre and Mèchain. The base measure, about 20 feet long, invented by the ingenious Mr. Joseph Saxton, by which the base lines have been measured in the Coast Survey triangulation, can recognise a delicacy of a hundred-thousandth part of an inch, and this trifling error is wholly imposed by uncertainties in temperature corrections. Such delicacy has not yet been attained in the European triangulation. See U. S. Coast Survey Report for 1854.

The well known French metrical system was first proposed in 1799, and adopted in most scientific calculations and measurements; but the people were not willing to accept it until the year 1812, when a sort of compromise was entered into; they agreed to take the length of the metre, but insisted on calling one-third of it a foot, and dividing it in the old natural way (binary), in accordance with which standards were made, distributed, and employed, until 1837, when the binary division was abolished, and the metrical decimal system finally enforced by law in the following form, to take effect after January 1, 1840: The metre to be divided and multiplied repeatedly by the arithmetical base 10; the cube of one-tenth of a metre to be the unit for capacity, and called *litre*, about a quart English measure; the weight of a cube of one-hundredth part of a metre (about a teaspoonful) of distilled water at its maximum density, to be the unit for weight, and called a *gramme*, about 16 grains, or two-thirds the weight of an American gold dollar. The units litre and gramme were decimally divided and multiplied; also, the solar day was divided into ten hours, each of 100 minutes, and each minute into 100 seconds. The chronological decimal system was decreed as compulsory with the new nomenclature of the calender November 24th, 1793, but this regulation was indefinitely suspended by law of April 7th, 1795, and in that case nature conquered the law.

Taking a general view of the metrical decimal system, and overlooking the absurdity of the arithmetical base, we find it a patching from beginning to end. The metre is not the intended right length; the unit for capacity is a $\frac{1}{1000}$th part of a cubic metre; the weight of a $\frac{1}{1000000}$th part of a cubic metre of water is the unit for weight; the metre is too long for practical application in the shop and the market; the gramme is too small, and the litre a reasonable size. The metre is the longest unit employed for ordinary measurement, and from my own observation on the actual performance of laying out work with the metre, and from comments made by Frenchmen, I believe it is too long to be convenient for the artisan, and when made for the pocket, a great many joints are required, which are objectionable in its application. The metre being divided into 100 parts, makes it inconvenient to divide the joints; ten are too many; four will contain the odd number, 25 centimetres or $2\frac{1}{2}$ decimetres, in each part, and five parts is not practical. When the artisan applies the metre, he cannot well see the correctness at both ends without placing himself in an inconvenient position, by which the correctness of the measure is liable to error, having myself been witness in Paris to the fact alluded to.

I have now here a great variety of the French metre, but none which I consider a proper and practical measure, and have never seen a good metre even in France, although I have made great efforts to procure the very best. Those here exhibited are mostly made to fold into ten parts, of ivory, brass, fishbone, and wood, which are the ordinary forms of the French metre; also, one a tape to roll in a case, and one a four-folding metre, as they are made in England; but they are all toys. About six years ago I bought a metre in Marseilles, of the ordinary ten-folding ivory form; at my hotel I tested it on my standard rule, and found it to be $1\frac{1}{2}$ millimetres too short; returning to the instrument maker, M. Santi, No. 6 Ferrol Street, I stated the fact, which was soon testified on a standard metre. I was then offered to select a correct metre, and tried a great many, but did not find two of the same length. Suspecting the great many joints to be the cause of error, I tried several by pushing and drawing, when I found a little motion in some of them; tried again two metres; the shorter one stretched a little, when it became the same length as the other. I selected one metre by the standard in the store, which I have here on the table; it has now grown nearly two millimetres longer when I stretch it out, and when I push all the joints in an opposite direction, it is half a millimetre too short. I do not blame the workmanship of the metre in question; it is made as well as it can be, and equally as good as those I selected in Paris, where I found similar objections; also in the metres possessed by the Decimal Association, London, attributed solely to the principle of the instrument.

It is very inconvenient to lay out work with the ordinary pocket metre; for instance, the metre must be kept and adjusted by the left hand at *a*, while stretched by the right hand at *b*; a third hand is then required to straighten the decimetres between *a* and *b*, because the

work is frequently such that if the hand is taken from *b*, that end will fall down and disturb the adjustment at *a*. In practice it often happens that it is inconvenient to get at one of the points between which a measure is wanted; a two-foot rule is then stuck over to the furthest or otherwise inaccessible point, and the measure read at the nearest point. In a great many such cases of daily occurrence, it would be impossible to apply direct a ten-folded metre, for which two hands are required, one at each point. Suppose the outside diameter of a cylinder is to be

measured; it is generally taken in a pair of callipers, which by the English mode is held by the left hand, with the foot-rule in the right hand, while the diameter is read; now by a French metre two hands must be employed to keep the metre, while a third hand is required for the callipers. You may remark that "the metre can be made to fold with hinges into four parts, similar to the English rule, and used with the same advantage." To which I reply, that a metre in such a form is rather clumsy for the pocket, and too slender for the artisan; its great length will not have the firmness of an English rule. The English four-folded metre is, however, the best form, of which I have here a sample; $2\frac{1}{2}$ decimetres or the odd number 25 centimetres in each part, clearly indicates that there is something wrong about it. Half a metre folded into two or four parts is a broken-up, half thing, two parts containing the odd number 25, and four $12\frac{1}{2}$ centimetres in each part.

The most important and well-known objection to the metrical as well as the decimal system in general, is, that it does not admit of binary division, as naturally required in the shop and the market. There is no country on the globe so deficient in metrology as England, and the next is America. The editor of the "Mechanics' Magazine" says:—"We fancy ourselves the practical and common-sense nation *par excellence;* but in what other country on earth are there different weights and measures for almost every different trade? and where else do weight and measure—nominally the same—vary in separate districts of the same kingdom?" England and America are truly the practical and common-sense nations, and that is just the very reason why we are worse off in metrology; had our arithmetic from the beginning been based on a practical scale, we would have been the first nations on the globe in possession of a most complete system of metrology. The metrical as well as the decimal system does not suit practical people, and therefore causes much difficulty and discordance in weights, measures, and coins. The French did not at first object so much to the new measure, but to the absurd decimal division.

The Decimal Association of London has lately, after many years labor, succeeded in getting their metrical scheme recommended by a committee of the House of Commons, after what they call a most careful inquiry and discussion. As the decimal system is unnatural and absurd, any reasoning attempting to defend it must likely be of the

same character, which is actually the case with that advanced by the London Decimal Association, which tells us that the metrical system admits of binary divisions! This is not ignorance on their part, for even if they have not sense enough to conceive that this is not the case, they have been told so repeatedly over and over again, and they know very well that the principal objection by all nations to the decimal and metrical systems is, has always been, and will always be, that it does not admit of binary divisions. The English branch of the International Decimal Association has many able and practical men as members, but unfortunately they seem to have taken no actual part in the proceedings, for the reports of the association lack sound and practical reasoning; they have repeatedly told us that "the best way of testing a measure is to measure cloth"!!! The leading members of the Decimal Association are men of high scientific attainments, but have little or nothing to do with the practical application of measures in the shop and the market; their object is a noble one, but the foundation of the decimal scheme is unnatural. The benefit of the decimal and metrical system to the few who have to do with measures merely by pen and ink, does not compensate the inconvenience it causes in the shop and the market.

I am sorry that we are not yet ripe to attempt to establish a system of arithmetic and metrology that would in all its bearings fulfil all requirements of mankind, but we propagate a halfway, patched-up system on a rotten foundation, to be abolished and a better one established by our descendants. I believe it is true, we do not yet deserve the honor of establishing a permanent system of calculation, for the reason that sound knowledge and practice are too little respected in our day, and on the other hand, practical men seem to care too little about general interests.

A uniform decimal (not metrical) system of metrology is now introduced in my native country, Sweden. It was given to the people in 1858, and enforced by law in 1862. In the year 1860 I had the pleasure of meeting Captain Carlsund in London, and asked him if he intended to introduce the decimal system into his establishment; when he answered, "We are obliged by law to introduce it, but allowed to use the old system yet for two years; the decimal system is unnatural and inconvenient in the practical application of measures."

Chambers, Bro. & Co. exhibited their improved Brick-making Machine. This machine tempers the clay, and moulds it into bricks at the rate of from fifty to sixty bricks per minute.

The clay is deposited on a platform over the machine, where the required amount of water is thrown upon it, and it is then shoveled into the machine, where it is ground or tempered by revolving knives set spirally into the shaft, and fed forward into a conical case, in which revolves a conical screw, that forces the clay through a rectangular die, forming it into a continuous bar, the proper breadth and thickness for a brick, which is conveyed by an endless apron sixteen feet, when

it is cut off at the proper length for bricks by a thin blade of steel secured to the periphery of a wheel, the velocity of which is controlled by the clay as it issues from the die; so that the wheel always makes one revolution for every brick-length of clay coming from the machine, thus insuring the uniform length of the bricks, no matter how irregular the flow of clay.

The bricks are carried off by an endless apron through a chamber, when a thin coating of sand is put on them by machinery, and they are then ready to be placed on barrows, and taken to the sheds to be hacked.

Specimens of bricks manufactured by this machine were also exhibited, which proved on examination to be very good and strong. One brick was exhibited, which had withstood a pressure of over 60 tons.

After the clay is delivered to the machine, it is converted into bricks ready to "hack" at a cost of twenty-two (22) cents per thousand, including engineer, machine tender, coal, and oil.

Several of these machines are in practical operation, making from twenty-five to thirty thousand bricks each per day. It is the invention of Cyrus Chambers, Jr., of this city, and has been in operation two seasons with very satisfactory results.

Mr. William McFarland exhibited a model of a Cupola Furnace, for which he obtained a patent from the United States, dated Dec. 7th, 1858, and which he described and explained as follows:

The object of my improvement in cupola furnaces is to prevent the collecting of the melted metal in the bottom of the furnace, and thereby keep the furnace free and in good melting order.

To accomplish this, I construct a reservoir of the same material as the furnace, and attach it to the furnace to extend below the level of the bottom, and communicating with the furnace by a passage, through which the melted iron and slag flows into the reservoir as soon as it reaches the bottom of the furnace. The reservoir and passage are lined with fire-brick the same as the furnace. The top of the reservoir I make of cast iron, which is securely fastened down, the lower side being coated with clay. The bottom of the reservoir I make to drop the same as the furnace.

In the common cupola furnace the melted metal and slag are collected in the interstices between the coal below the tuyeres, and for the purpose of making room enough to hold the metal required, the tuyeres are placed from ten to twenty-four inches above the bottom, according to the kind of work made. With my reservoir attached, six inches is all the space required below the tuyeres, thereby saving from four to eighteen inches of fuel in the bed. In the common cupola furnace, as the melted metal accumulates and rises, the slag being lightest floats on the surface, and is carried upward amongst the coal; as it approaches the tuyeres, the direct action of the blast on it chills some and turns it black, thus forming a nucleus for more to accumulate as it ascends or descends. This again forms an obstruction to the

melted metal as it drops down, some of which is chilled by coming in contact with the cold slag. The chilled iron and slag thus continue to accumulate all through the heat, and it frequently happens that a furnace which will hold 1200 pounds of melted iron at the beginning will not hold 200 pounds at the end of a heat, and that having lost its fluidity to such a degree (by coming in contact with so much dead matter in the bottom of the furnace) as not to be fit for casting. With my reservoir attached that difficulty is obviated, as the melted iron and slag flows into the reservoir immediately on reaching the bottom of the furnace, thereby keeping the furnace cleaner and in better melting order.

In the common furnace, owing to the accumulation of chilled iron and slag, the blast is so obstructed that it cannot pass through the fuel freely, thereby impairing its melting properties, and rendering the metal less fluid. With my reservoir attached, the iron and slag having free egress from the furnace, less obstruction is offered to the blast; it circulates through the fuel better, effecting a more perfect combustion, and with less fuel melts quicker, and the melted metal is of a more uniform temperature throughout. By using the reservoir, at least two-thirds of the iron usually dropped with the stock from the bottom of the furnace after a heat is saved, and as no chilled iron accumulates on the sides of the furnace, the brick lining is injured less in cleaning it out.

Mr. Washington Jones exhibited Messrs. Springer & Weaver's improved Letter-box, recently patented by J. H. Springer. Within this box, which in exterior form resembles the ordinary letter-box, are two inclined plates, one of these plates being so placed beneath the opening that the letters when introduced into the box will fall on the said plate and be carried towards the back of the box, where they will strike the second plate, and be guided to such a position beneath the first that they cannot be withdrawn by any instrument introduced into the box through the opening.

Mr. Washington Jones also exhibited S. M. Perot's Army Medicine Wagon. The different cases or boxes containing the medicines are so arranged in the wagon, that a central space is left, forming an apartment in which to compound medicines, the cases opening towards the interior of the apartment so that the attendant is completely protected during stormy weather, when otherwise it would be a matter of extreme difficulty to make accurate measurements of medicines. Secured to the outside of the wagon, so as to be readily detached, are a number of hand ambulances and other articles needed for sick or wounded soldiers. In case of necessity, by slightly altering the position of one of the cases, room may be afforded in which to seat six or eight men.

Mr. Edward Lane exhibited his patented improvement in Hanging Carriage Bodies. In this invention the body rests on four levers, D,